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The influence of potassium fertilization and plant population upon the performance of several corn hybrids

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TABLE OF CONTENTS

INTRODUCTION

The requirements for K fertilization of corn (Zea mays L.) have been fairly well established for most Iowa soils, but a constant need exists for some reevaluation in terms of changing management practices, economic conditions, new genetic materials, insect and disease incidence, and other production factors. Such studies need to be concerned not only with total yields but should attempt to consider the influence of K fertilization on the various individual components controlling plant yield and quality.

Despite the introduction of improved hybrids, poor stalk quality and associated plant lodging continue to be problems in corn production under some conditions. Many factors, some genetic and others environmental, contribute to stalk and root lodging resistance or susceptibility in corn. Among the genetically conditioned aspects of lodging resistance are numerous morphological traits, anatomical stuctures, and inherent resistance to insects and plant pathogens.

Although soil fertility may not be the most important factor affecting stalk quality and lodging, it does have a significant effect and is one factor within control of the corn producer. Much research has been conducted in which fertility treatments have been observed to markedly influence lodging of field corn. Lodging resulting from poor fertility has usually been associated with low levels of K. Evidence indicates that N fertilization, especially if in excess compared with K, increases lodging. While K fertilizer usage has increased in recent years, the usage of N fertilizer has increased more rapidly. The use of higher rates of N fertilizer may have offset the success of the plant breeder in his attempt to identify superior stalk quality and stalk lodging resistance traits. Additional information is needed regarding the level to which K influences stalk quality and the mechanism of its action.

The trend toward higher plant population in recent years has often accentuated the lodging problem, possibly because of more stress on the soils ability to supply the required nutrients and less mechanical resistance of smaller diameter plants. Evaluation of the fertility needs of plants grown at higher plant populations is needed both from a yield and stalk quality standpoint.

Considerable interest has recently developed regarding the potential for prolific-type corns in the North Central states, where single-ear hybrids are the standard type. Prolific hybrids have been shown to be less subject to genotype by environment interactions than adapted single-ear types. Some of these hybrids have shown excellent yielding potential in tests but have tended to have poor stalk quality under many growing conditions. Even with adequate N and P on soils deficient in exchangeable K there has been tissue breakdown in the stalk leading to lodging problems by maturity or harvest time. It was thought that these hybrids would make excellent test crops for further study of the effect of K on lodging and stalk quality and changes in the K needs for variable plant populations from a yield standpoint. Such information should be useful to growers considering the use of these hybrids, as well as to plant breeders continuing work on their development.

This study was carried out in order to further characterize the effect of K fertilization and plant population upon the growth, standability, chemical composition, and yield of several corn hybrids.

REVIEW OF LITERATURE

Forms of Soil K Used as a Criterion in Determining Plant Responsiveness to K Additions

In soil, K occurs in three forms: (a) soluble K, (b) exchangeable K, and (c) nonexchangeable K that is present either as an original constituent of the soil particles (native K) or as added K that has been fixed. The exchangeable K is that K which can be displaced from the soil by using neutral 1 N NH_4OAc solution as an extracting agent while the nonexchangeable K is that which is not extracted by such a treatment.

An equilibrium exists among the various forms of soil K. The soluble and exchangeable forms are regarded as being readily available to plants whereas the nonexchangeable is not. The amount of K in the soil solution at a given time is usually not sufficient to meet the major part of the requirements of a crop. During a cropping period plants may deplete the soil of water soluble and exchangeable K until they are below the equilibrium levels. As a result, some of the nonexchangeable K may be released to exchangeable and water soluble forms and thereby become available to the plants. Thus, the productiveness of a soil, with respect to K, must depend to a large extend on its ability to maintain a concentration of K in the soil solution adequate to meet the demands of the plant.

A number of investigations have been conducted in an effort to relate a particular form or forms of soil K to that available for plant utilization. Good discussions on the equilibrium between the various forms of K in the soil are to be found in the reviews of Reitemeier (1951) and Wiklander (1954). Nelson (1959) compared several methods for evaluating the K status of some Mississippi soils. The best correlations between K uptake by plants and the amount of extracted soil K were obtained with those chemical methods measuring exchangeable K.

Evidence indicates that the exchangeable K in soil should be determined with field moist samples. The work of Leubs et al. (1956) on 13 Iowa soils with corn, field studies with alfalfa on soils of the North Central region of the United States, Ontario, and Alaska by Hanway et al. (1961), greenhouse studies with millet on soils of the North Central region of the United States and Alaska by Barber et al. (1961) and field studies with corn on soils of the same region by Hanway et al. (1962) all show that K uptake by crops correlates better with exchangeable K determined on moist soil than on air dry or oven dry soil.

Influence of K Added in Organic Residues and Fertilizers on the K Content of Soils and Yields

Potassium is not definitely known to be incorporated into organic compounds essential for the existence of the plant. It occurs in plants primarily as soluble inorganic salts. A considerable amount of K may be returned to soils each year in the unharvested portion of the above ground parts of plants as well as the root system.

The beneficial effect of K added in crop residues on the more available forms of soil K has been recognized for quite some time.

Conner and Abbott (1912) noted improved yields as a result of fresh straw turned under in studies of "black soils" in Indiana. Several investigators (Harper, 1925; Hunter and Hammer, 1952; and Sears, 1933) have demonstrated that K added in the form of mulching material or crop residues enhances the more available forms of K in the soil.

Wander and Gourley (1938) presented data which show the exchangeable K level in soils to be very high to a depth of from 24 to 32 inches as a result of maintaining a heavy wheat straw mulch on orchard soils for a period of 22 to 38 years. Moser (1942), reporting on the influences of leguminous plant additions, found that eight annual applications of rye and vetch, in rotation with cotton, increased the exchangeable K level in soil from 64 to 107 ppm. Three annual applications of four tons of crimson clover, incorporated or added as a mulch, increased exchangeable K levels from 54 to 145 and 54 to 142 ppm, respectively. Grimes and Hanway (1967a) have shown that the K in crop residues is as available for plant utilization as is K added as KCl. It was shown that essentially all of the K contained by corn stalks had diffused into soil within 72 days when residues were placed in close contact with moist soil. In an experiment conducted to study the effect of crop residues and seasonal cropping on exchangeable soil K Grimes and Hanway (1967a) found that increasing the duration of meadow in the crop rotation extensively reduced the exchangeable soil K. The addition of 25 pounds of K per acre for each year of meadow beyond the first was not sufficient to offset the removal of K in the hay crop. Where 25 pounds of K per acre were added each year to continuous corn, the exchangeable

K level of the soil was maintained considerably higher than for plots having one or more years of meadow in the crop rotation. Within a specific crop rotation the exchangeable K level increased because of K additions from corn residues and declined when meadow was grown in the sequence. This effect resulted in a cyclic trend within the rotation and indicates that the exchangeable soil K level strongly reflects K additions from crop residues.

Hoover (1943) sampled soils from 10 locations where fertilizer tests had been conducted in various parts of Mississippi, and found that K accumulated in the A horizon in replaceable form when applied annually in excess of the plant needs and that this accumulation increases as the rate of application increases. Hoover also found that on soils having less than 0.20 milliequivalents replaceable K per 100 grams of soil (156 pounds per acre), cotton may be expected to respond to the application of K if the supply of N and P is adequate. On soils having more than 0.30 milliequivalents replaceable K per 100 grams of soil (234 pounds per acre), no response to K fertilizer may be expected. Winters (1945) correlated the levels of available soil K and the response from K fertilization on field experiments conducted with five crops in several sections of Tennessee. The average yield increases from K fertilization were greater in every case on the soils with the lower exchangeable K levels. The yield-response curves for all crops studied indicated the following approximate levels of exchangeable soil K above which K fertilization ceased to give significant increases in yield: corn, 155 pounds per acre; alfalfa, 160; cotton, 185; tobacco, 190;

Irish potatoes, 220. Bray (1944) found the K requirement for corn on Illinois soils to be 155 pounds per acre. In a study in which K fertilizers were applied at different rates for corn in six North Central states during 1957 and 1958 Hanway et al. (1962) found the average increase in K content of the plants resulting from K fertilizer application was equal to 23 percent of the amount applied. Uptake of K fertilizer was inversely related to the level of exchangeable K in the soil. Grain yields were increased significantly by K fertilizer applications in only 11 of the 41 field experiments that were harvested. There were no significant yield increases where the exchangeable K level exceeded 160 pp2m except on an organic soil which had 192 pp2m of exchangeable K. Barber et al. (1961), working with corn, found that above a value of 200 pounds of exchangeable K per acre there was no response to applied K. Peck et al. (1965) found that soil K accumulated to medium-high levels in the soil during 7 years of K fertilization. Eight years after no further application of fertilizer there was still a significant residual effect of exchangeable K in one of the two fields used in the study. Barber (1970) studied the effect of K fertilization on the first, second, and third corn crops following the application on Chalmers silt loam soil. The results of the experiment indicated that at rates commonly used by farmers the effect of K will last for only two years on soils similar to Chalmers silt loam where the initial soil test was at the 160 pound level. Because this soil fixes K in an unavailable form, Barber concluded that it may be feasible to get an effect lasting more than two years on soils which fix less K. White and Doll (1971) found that K additions of 2 to 4.5 pounds were required to increase the exchangeable K level 1 pound depending upon the soil texture. Soils with high percentages of clay required more K fertilizer to increase the exchangeable K levels in the soil because of K fixation. In a $2^n + 2n + 1$ central composite design involving five levels of N, P, K, and limestone applied to continuous corn during a period of eight years, Bohling (1971) found that the increases in the exchangeable K level in the soil were proportional to the amount of fertilizer K applied. No response to applied K was found when the level of exchangeable K exceeded approximately 200 pounds per acre.

Influence of Soil Fertility on Lodging of Field Corn

The effect of K on lodging of corn has been the subject of numerous investigations. Lang and Baurer (1939) found a great variation among corn hybrids with respect to K utilization. In a study of two hybrids on K-deficient and K-supplied soil, they found that both hybrids lodged badly when grown on K-deficient soil and that on K-supplied soil one hybrid continued to lodge but the other showed little lodging.

Krantz and Chandler (1951) found that additional applications of K fertilizer to soil with sufficient K to cause no deficiency symptoms did not affect yield or lodging. When K was applied to soils on which plants showed deficiency symptoms, lodging and stalk breakage was decreased and yield was increased. Nitrogen applications markedly increased yield, but caused only a slight increase in lodging. The authors reported that the N treatments did not greatly influence lodging until plant populations reached the 15,000-20,000 plant per acre range. They concluded that low levels of K, high plant populations, and varietal differences were all of greater importance in their effect on lodging than was the application of N.

Wittels and Seatz (1953), using rates of N of 60 and 120 pounds per acre, observed no further consistent decrease in the amount of stalk breakage or yield increase over the check plot at K applications greater than 40 pounds per acre. At the lower K level, stalk breakage was less severe in the low N treatments than in the high N treatments.

Otto and Everett (1956) reported that in general the severity of stalk rot increased with increased applications of N and decreased with an increased supply of K. Where the N:K ratio was balanced, stalk rot was less severe than when an excess of N was present. They concluded that from their study, it appeared that the greatest promise for control of stalk rot lies in the use of resistant hybrids on soils where the N supply is not exceedingly high in relation to K supply.

Foley and Wernham (1957) reported that applications of N alone greatly increased the severity of internodal rot, stalk breakage, and premature dying but that application of K alone had the opposite effect. When the N and K level was high, the addition of P had no effect on development of internal rot and the amount of stalk breakage, but it did increase the amount of premature dying.

Fisher and Smith (1960) grew corn at 8,000 plants per acre and concluded that lodging was significantly increased by applications of N alone or in combinations with P. Potassium reduced lodging significantly when applied with N and P. Maximum lodging (70%) occurred with 120 pounds of N per acre and 66 pounds of P per acre applied in the absence of fertilizer K. The addition of K to this combination reduced lodging to 34%, while grain yield increased 28 bushels per acre. Koehler (1960) also found that the percentage of rotted stalks increased with the application of N alone or in combination with P. But when K was applied in combination with N and P, stalk rot percentages decreased.

Studies by Murdock, Stangel, and Doersch (1962) show little or no effect of N, P, or K alone on lodging, however, the combination of high levels of N and P without K produced about 65 percent lodged corn. Applications of K along with N and P reduced lodging to about 15 percent. Observations made on stalks from the badly lodged plots indicated the presence of stalk rot.

In a 2-year study Josephson (1962) obtained very high correlations (r = .93 and .98) between the percent of senescent stalks at harvest and percent stalk breakage. He reported that addition of K decreased percent senescent stalks and lodging.

Liebhardt and Murdock (1965) observed that K deficiency resulted in severe lodging of two distinct types. Root lodging, due to restricted brace root development and root failure, occurred early in the season. Stalk breaking occurred later in the season and was due to stalk parenchyma disintegration. Potassium deficiency resulted in breakdown of parenchyma tissue in both roots and stalks.

Methods of Evaluating Stalk Quality in Corn

The incidence of stalk breakage in the field is a complex phenomenon. The process itself is affected by the interrelationships of various factors, and the evaluation is usually confounded by numerous variables of the environment. The field-count method served satisfactorily in the past as evidenced by the improvements which have been made. The field-count method, however, is seriously dependent upon environmental forces. Optimum environmental forces do not occur with satisfactory frequency. Continued improvement for lodging resistance depends upon evaluation techniques which are largely independent of environmental forces.

Mechanical methods which are related to field stalk breakage of corn have been used for measuring strength of stalks. Durrell (1925) placed stalks horizontally on 2 supports spaced 6 inches apart with the node midway between them. He applied downward pressure on the node with a lever device and recorded breaking strength of the first five nodes above the ground. From lower to higher nodes, strength decreased successively. Nodes showing fungal infection had about one-half the strength of uninfected nodes.

McRostie and MacLachlan (1942) determined strength of four successive internodes per plant by breaking, crushing, and penetration measurements. Resistance to breaking, crushing, and penetration decreased successively from low to high internodes. Resistance of internodes to crushing appeared to have the highest correlation with resistance to lodging.

Jenkins (1930) evaluated the relationship between the breaking strength of stalks and percentage of plants broken in the field in 46 selfed lines. Breaking strength was measured on a machine designed and built for that purpose. The correlation coefficients for the breaking strength at three internodes and field stalk breakage were: 3rd internode - 0.5766, 4th internode - 0.5588, and 5th internode - 0.4915.

Jenkins and Gaessler (1932) found in comparing the short diameter, long diameter, and cross section area of an internode that the short diameter gave the highest correlation with percentage of broken plants in the field.

Foley (1962) determined strength of 4 of the lower internodes of corn hybrids varying in resistance to stalk rot by measuring the force required to break 6-inch sections. Nine hybrids tested at various times during August, September, and October had strong stalks in August regardless of susceptibility to stalk rot. In October, stalks of susceptible hybrids had deteriorated due to stalk rot to as much as one-fifth of the original strength. The lower internode had greater inherent strength than upper ones, but they suffered a great percentage loss in diseased plants. In susceptible hybrids, losses of stalk strength were evident in late August, usually prior to the appearance of typical symptoms.

Zuber and Grogan (1961) evaluated the association between stalk lodging and various stalk characteristics. Highly significant, negative correlations were found between stalk lodging and breaking strength of the second internode, stalk lodging and dry weight of a 2-inch section of the second internode, stalk lodging and thickness of rind of the third internode, and stalk lodging and crushing strength of the third internode. The general description of the techniques for measuring crushing strength and rind thickness was presented by the authors and also by Zuber and Loesch (1962).

Loesch, Calvert, and Zuber (1962) found that rind thickness was not affected by _Diplodia maydis_ infection, but stalk-crushing strength of lodging-susceptible single crosses was reduced. The authors concluded that selection for stalk strength _per se_ by measuring the thickness of rind, crushing strength, and selecting for resistance to stalk rotting organisms offered an excellent opportunity to develop corn hybrids with superior stalk lodging resistance.

Thompson (1964) suggested that any internode below the ear would be satisfactory for determining crushing strength, rind thickness, internode diameter, and internode length, that sampling should be confined to a specific internode for all plants, and that data should be obtained from more than one location for crushing strength and rind thickness.

Thompson (1970) reported that specific gravity computed as dry weight/green volume of 50-mm stem sections of corn was significantly correlated with stalk lodging, stalk rot rating, and crushing strength.

Loesch (1972) found that the weight of a 2-inch stalk section was well suited for rapid screening purposes. Highly significant, negative correlations were found between stalk lodging and weight of stalk section, stalk lodging and crushing strength, and stalk lodging and rind thickness.

As early as 1957, Pappelis (1957) correlated resistence to stalk rot with the density of pith tissue in the corn stalk. Wysong and Hooker (1966) concluded that senescent tissue was incapable of resisting invasion or spread of stalk-rotting organisms. Cloninger et al. (1970) compared the stalk crushing method, the Diplodia stalk rot rating method, and the pith condition method of determining stalk quality in maize. They concluded that all methods were valid estimates of stalk quality.

Miller and Myers (1974) concluded that the selection for pith cell death should be an effective tool for selection of superior standing lines.

Interaction of K with Other Nutrients

The most frequently observed interactions of K with other nutrients is the interaction of K with Ca and Mg. Additions of K will frequently reduce the Mg content of the corn plant and may induce a Mg deficiency on soils low in Mg. The negative correlation between Mg uptake and exchangeable K is frequently better than the positive correlation between Mg uptake and exchangeable Mg.

Stanford et al. (1942) emphasize that the antagonistic effect of K on the absorption of Ca and Mg becomes pronounced with increasing concentrations of K and caused a reduction in the absorption of these divalent cations. This phenomenon led Walsh and O'Donohoe (1945) to conclude that the soils on which they observed Mg deficiency had ample exchangeable Mg but too high a level of K. Prince et al. (1947) considered the availability of soil K to be the most important factor influencing plant absorption of Mg. If there was an abundant supply of available K in the soil the Mg content of the plant was relatively low.

Reciprocal effects of Mg and K were found by McLean (1950) in a study of cationic activities in clay suspensions. Except in the halloysite system, the fraction active of Mg decreased rapidly with increasing K saturation, particularly in the montmorillonite system where Mg activity was too low to be measured when more than 5 percent of the exchange complex was occupied by K. In Missouri, Graham et al. (1956) found that a response to Mg fertilization is expected when the percent Mg saturation of soils drops below 10% of the exchangeable cations.

Boswell and Parks (1957) studied the effects of K fertility levels on yield, lodging, and mineral composition of five corn hybrids. In all hybrids, increased K fertilization generally decreased the leaf content of Ca and Mg, but did not affect the P content appreciably. The K content of the plants in the check plots was approximately 1.2%, Ca 0.8%, Mg 0.9%, and P 0.3%, whereas in plots with high K fertilization, the K content was about 3.5%, Ca 0.5%, Mg 0.2%, and P 0.3%. At the 175- and 275-pound K_2O levels, the milliequivalents of total cations were almost a constant for all sampling dates.

Foy and Barber (1958) conducted field experiments on two acid, sandy loam soils of northern Indiana to determine the influence of Mg, calcitic lime, and K on yields, Mg deficiency symptoms, and leaf composition of corn. On one soil K treatments induced widespread Mg deficiency symptoms. Their identity was confirmed by low Mg and high K contents of leaves. The occurrence of Mg deficiency symptoms was not accompanied by a reduction in corn yield.

Gorsline et al. (1961) found that differential ear-leaf accumulation of Ca, Mg, and K existed for single crosses and inbreds of maize. This differential accumulation was highly inherited on essentially an additive basis in respect to Ca and Mg but included nonadditive elements for K. Location effects for Ca, Mg, and K existed that were related to the amounts of these elements in the soil. Baker et al. (1966) also studied the range in K, Ca, and Mg among different genotypes. The range between the low and high values for the different elements was as follows: K, 29 meq; Ca, 29 meq; and Mg, 22 meq. Embleton (1966) has listed many crops reported to develop Mg deficiency due to K additions to soil or culture medium.

The theory of cation- and anion-equivalent constancy has been frequently expressed and numerous data are available supporting this contention in varying degrees. According to this idea, as a plant absorbs greater quantities of a particular ion, a corresponding chemical equivalent decrease occurs in the absorption of other ions of like charge. Van Itallie (1938) showed that when rye grass was grown on a soil receiving different quantities of calcium, potassium, magnesium, and sodium, the relative absorption of the individual cations changed markedly with the treatments but the sum of the four elements in the plant, expressed in chemical equivalents, remained essentially constant. Bower and Pierre (1944) applied K to several different crops grown on a "high-lime" calcareous soil. Potassium additions decreased the Mg content of the crop and increased yields. With corn the Mg content decreased 52 meq and K increased 58 meq while yields were more than doubled. The cation sum in the case of corn did not change significantly. Bear and Prince (1945), Lucas and Scarseth (1947), Wallace, Toth, and Bear (1948), York, Bradfield, and Peech (1954), Boswell and Parks (1957), and others have observed that the total number of equivalents of the cations absorbed by many crops may remain relatively constant despite wide variations in absorption of individual cations.

Effect of Plant Population on the Performance of Corn Hybrids

Plant population experiments with corn have been conducted at many of the agricultural experiment stations in this country. Morrow (1891) summarized early experiments in Illinois by stating that corn can be planted either too thick or thin, and that the optimum rate varies with latitude, soil, and variety. Richey (1933) summarized experiments with open-pollinated varieties in the United States and concluded that the optimum stand of corn becomes heavier as one proceeds from genetically larger to smaller plants, from low to high moisture supply, and from low to high soil productivity.

Previous studies on plant populations and stand irregularities in general have shown certain patterns. Dungan et al. (1958) have summarized the literature on the subject. A decrease in area per plant was usually accompanied by a decrease in weight of grain per plant and ears per plant, and an increase in stalk breakage and days to mid-silk. This is no doubt caused by a decrease in the supply of environmental factors of yield that each plant is forced to share with its competing neighbors.

A study by Bryan et al. (1940) revealed that plants from the highest rate of planting (20,000 plants per acre) produced the smallest ears and the fewest ears per 100 plants. The smallest number of plants per acre (10,000) produced the largest ears and the most ears per 100 plants. Other spacings were intermediate in ear size and number. The difference in yield between the highest and lowest population was 3.1 bushels, which was not significant. The reduction in ear size and number was offset by the greater number of plants at the higher populations. Planting rate also had a decided effect on the incidence of lodging. Lodging was most severe at the highest plant density and decreased significantly as plant density decreased.

Plant spacings of 1, 2, 4, 8, 16, 32, 48, and 64 inches were used by Haynes and Sayre (1956) to study the effect of within-row competition on several plant characters of corn. Each plant spacing was represented by a single-row plot 75 feet long. An interspacing between plots of $8\frac{1}{2}$ feet was provided as a safeguard against between-row influence. The authors found an increasing number of barren plants combined with decreasing weight per ear at the excessively close plant spacings. The largest weight per ear occurred between the 8- and 16-inch spacing between plants in the row. The increasing tendency to set more than one ear at the wider spacings caused a decrease in the average ear size.

Lang et al. (1956) obtained ears averaging 0.71 lb at a population of 4,000 plants and 0.54 lb was obtained from 12,000 plants per acre which corresponded to the highest average yield for all hybrids at all fertility levels. Stalk barrenness was affected more by population than by hybrid or fertility level. However, all three factors affected barrenness significantly. At the 4,000- and 8,000-plant levels, there was not an earless stalk. On the low-nitrogen level soil, 33% of the stalks were without ears at the 24,000-plant level. With the same stand on the high-nitrogen level, only 16% of the stalks were barren. Hybrids which showed a tendency to be multiple-eared at low population rates had the lowest percentage of barren stalks at the high plant populations.

Woolley et al. (1962) studied the effects of plant populations and spacing patterns on the performance of four corn inbreds in single-cross hybrids. The number of barren stalks and days between pollen shedding and silking were strongly influenced by plant population. As the number of plants per acre increased from 16,000 to 24,000 there was a significant increase in the number of days between pollen shedding and silking. Plant barrenness, which increased linearly as the plant population increased had a marked influence on yield at high populations. All hybrids showed a decrease in seed weight as the population level was increased. The differences were not judged to be significant, however.

Colville and McGill (1962) found that certain disadvantages occurred with increased plant populations. Lodged and broken plants, kernel moisture, and ear height increased as populations were increased from 12 to 28 thousand plants per acre. A slight delay in maturity was indicated by a 0.37% increase in kernel moisture as populations were increased by 4,000-plant increments. Lodging increased approximately 2.4% with each increase of 4,000 plants per acre. Stalk diameter showed a linear decrease with increasing populations. A difference in ear height of 7.5 inches was noted between the 12,000 and 28,000 plant populations. The authors pointed out that a higher ear placement would put more leverage on the stalk and could account for some of the increase in broken and lodged stalks.

Duncan (1958) using data obtained from the literature and other sources which gave yields and populations of corn showed that within the range of populations studied the relationship between the logarithm of the average yield per plant and the population was essentially linear. Duncan hypothesized that for normal corn it seems conservative to assume that the linear relationship is maintained between populations of 6,000 and 25,000 plants per acre, under usual conditions in the corn belt.

The formula for the relationship is expressed by equation (1) as follows:

$$\text{Log } y = \text{Log } K + bP, \text{ or } y = K10^{bP} \qquad (1)$$

where y is the yield per plant

K is a constant

b is the slope of the regression

P is the population in plants per acre

Y is the yield per acre

Since yield per acre is the product of yield per plant and plant density, he multiplied the yield per plant equation by plant density to obtain an equation for yield per acre.

$$Y = yP \tag{2}$$

Substituting the value of y from equation (1) gives:

$$Y = PK10^{bP} \tag{3}$$

Duncan pointed out that use of such equations permits estimation of the maximum yield of a variety and the plant density producing that yield from trials with as few as two plant densities per variety. Duncan also pointed out that the relationship and equations should be useful in the field of fertility research. In all of the data observed in his study, increasing N levels in the soil increased the number of plants needed for maximum yield. If corn in a N treatment trial were grown at a single population, the effect of the N added would be greatly affected by the population chosen.

Warren (1963) used a similar pattern of equations to describe the effects of plant density on yield of fresh market sweet corn. These equations differed from Duncan's in that the basic equation used a linear relation between plant density and yield per plant, rather than log yield per plant. A parabolic function was obtained for yield per acre instead of an exponential function. Warren's yield equations also can be obtained from as few as two plant populations per variety.

Most of the information available on stand effects was obtained from single-eared hybrids. This information may not necessarily apply to prolific (multiple-eared) hybrids. Considerable evidence indicates that genotypes capable of producing grain on more than one ear are less subject to genotype x environment interactions than adapted single-eared genotypes. Prolific hybrids planted at a low rate may adjust better to variable environments than nonprolific hybrids by producing a single-ear per plant under adverse conditions and more than one ear when conditions are more favorable. Single-eared hybrids adjust only by changes in the size of the ear and to a lesser extent, kernel size.

Zuber et al. (1960) found prolific-type corn in Missouri to produce more grain per plant than the single-ear types regardless of planting rate. Planting rates of 8,000, 12,000, and 16,000 plants per acre were used in their comparisons. The average number of ears per plant decreased with increases in planting rates. Single-ear hybrids were strictly one-ear types at 12,000 and 16,000 populations, whereas prolific types tended to bear more than one ear per plant at those rates. The greatest range in average ear weight was shown in single-ear types.

Collins et al. (1965) showed that the yields of the prolific-type corn used in their study varied less than the yields of the single-ear type across plant populations of 8-, 12-, 16-, and 20-thousand plants per acre. Estimates of the plant population which would produce the maximum yield per acre indicated that the prolific-type crosses may perform better in higher plant populations than the single-ear type crosses. At the 8,000 plants-per-acre population 83% of the plants of the prolific-type produced 2 ears. Second-ear production decreased significantly at the 12,000 and 16,000 plant populations.

Crews and Fleming (1965) studied the effect of stand on a prolific and a nonprolific hybrid with reference to yield and other agronomic characteristics. Yield per plant increased significantly with increased space per plant with both hybrids. With a significant increase in ear size, plants of the prolific-type had a greater increase in yield than plants of the single-ear hybrid as space per plant increased. The increased yields per plant were not large enough to fully compensate for the missing plants, however, and yields per acre decreased significantly as plant densities were decreased from 11,000 plants per acre. Stand and yield reductions were not proportional. When the stand was reduced to 47% of the check, the yields were reduced to 70 and 63% for the prolific hybrids, respectively. There was a tendency for increased lodging as the number of plants per plot increased, but the differences were inconsistent and nonsignificant.

Russell (1968) suggested that the advantage of the two-ear inbred lines is not in the production of second ears in the hybrid combinations, but in the resistance to barrenness exhibited at higher stand levels. Russell found the single-ear type had 11.9% barren stalks at 24,000 plants per acre. Yields were reduced 10.5% from the 16,000 plants per acre planting rate. The prolific-type had only 3.0% barren stalks which was not enough to cause a yield decrease from the 16,000 planting rate.

METHODS AND PROCEDURES

Field Procedures

Location of sites

Nine K rate x plant population experiments were conducted during the 1972, 1973, and 1974 growing seasons. Experimental sites were selected on four Iowa State University experimental farms, the Clarion-Webster Experimental Farm (CWEF) in northcentral Iowa, the Western Iowa Experimental Farm (WIEF) in western Iowa, the Southern Iowa Experimental Farm (SIEF) in southern Iowa, and the Bruner Farm which is part of the Agronomy and Agricultural Engineering Field Research Center (AF) in central Iowa. The soil types at each location are Webster silty clay loam, Ida and Monona silt loam, Edina silt loam, and Webster silty clay loam, respectively.

In 1971 experiments were conducted on the CWEF and SIEF sites to study the effectiveness of several K sources as components in row fertilizers for corn and the relative value of K fertilizers in row and broadcast applications. The K sources used in the row were applied in combination with different basic levels of plow-down K in a split-plot, randomized block design. The plow-down K treatments were applied to the whole plots, with the K sources in the row serving as split-plot treatments. Each treatment was replicated six times. Since observed source differences were nonsignificant, it was decided that these sites, with different established levels of soil K, be used to characterize the effect of K fertilization and plant population upon the performance of several corn hybrids. In 1972 the plow-down K treatments were reapplied to the same plots at the CWEF and SIEF sites and a third experiment was established on the WIEF site. In 1973 the experiment on the SIEF site was of necessity discontinued and a fourth experiment was established on the AF site at Ames, Iowa. The CWEF, WIEF, and AF sites were used in 1974, also.

Design of experiments

The experimental design used in this experiment was a split-plot design with K treatments applied to the whole plots and stand levels serving as subplot treatments. Each treatment was replicated six times.

Three rates of K were used at the CWEF, WIEF, and SIEF locations: 0, 50, and 200 pounds of K per acre. An additional rate of 100 pounds of K was included in the design at the AF site to provide a more complete response curve.

These treatments were assigned to the plots within a block in a randomized complete block design. A whole plot size of 40 x 60 feet was selected to accommodate twelve, 40-inch rows at the CWEF, WIEF, and SIEF sites and to accommodate sixteen, 30-inch rows at the AF site.

The hybrids were planted across the fertilizer blocks in three-row subplots at plant populations of 10-, 20-, 30-, and 40,000 plants per acre on the CWEF and SIEF sites and at stand levels of 8-, 16-, 24-, and 32,000 plants per acre on the WIEF site. Four-row subplots at plant populations of 10-, 20-, 30-, and 40,000 plants per acre were used on the AF site. Subplot stand treatments were randomized within each whole plot.

Characterization of plots

Prior to each fertilizer application, soil samples consisting of 10 to 15 cores were taken from the 0 to 6 inch layer of each whole plot. Measurements of soil pH, buffer pH, available P and exchangeable K were made on these samples by the Iowa State University Soil Testing Laboratory. The range of the soil test results for the initial samples are given in Table 1.

Table 1. Range of soil test values for the initial soil samples taken prior to fertilization

Experiment	Soil type	Soil test values P(pp2m)	K(pp2m)	pH
CWEF	Webster Sicl	33-51	105-141	6.4-7.3
WIEF	Ida Sil	3-21	80-154	8.1-8.2
	Monona Sil	21-64	100-144	6.8-8.1
SIEF	Edina Sil	14-36	63-87	6.0-6.9
AF	Webster Sicl	10-41	97-181	5.8-6.5

Management factors

The standard cultural practices used on the outlying experiment farms were employed in these studies. The general practice was to fall plow and to do enough disking in the spring to provide a good seedbed. As a soil and water conservation measure, spring plowing was practiced on the WIEF site.

Weed control methods varied to some extent among sites. Chemicals as well as cultivations were used in all cases. Where these practices were ineffective, weeds were controlled by hand hoeing.

All sites received basic applications of approximately 250 pounds of N and 100 pounds of P_2O_5 per acre each year.

The K fertilizer treatments were broadcast by hand and plowed under in early spring at each site in 1972. Potassium chloride was used as the source of K throughout the study. In 1973 and 1974 the K fertilizer treatments were applied to the experimental plots in the fall before plowing at the CWEF site and in the spring before plowing at the WIEF site. A spring application of K was made in 1973 at the AF site followed by a fall application for the 1974 growing season.

The corn hybrids used in 1972 were Northrup King Experimental Hybrid X26 on the CWEF site and Farm Service FS860 on the SIEF and WIEF sites. In 1973 Farm Service FS860 was used on all sites. A single cross hybrid B37 X B70 was planted at all locations in 1974. The hybrids were planted to provide stand levels of 10-, 20-, 30-, and 40,000 plants per acre at the CWEF, SIEF, and AF sites. Anticipating less favorable moisture conditions at the WIEF site the test populations were reduced to 8-, 16-, 24-, and 32,000 plants per acre. The stands were obtained by overplanting and hand thinning to the desired level. Planting and harvest dates for each experiment are given in Table 2.

Table 2. Management factors pertaining to crop planting and harvesting and K fertilization at individual sites each year

Experiment	Year	Planting Date	Harvest Date	K Fertilization Date
CWEF	1972	May 9	Oct 16	April 25, 1972
	1973	May 12	Oct 25	Nov 17, 1972
	1974	April 30	Oct 24	Nov 6, 1973
SIEF	1972	May 18	Oct 26	April 18, 1972
WIEF	1972	May 10	Oct 24	April 13, 1972
	1973	May 11	Oct 16	April 18, 1973
	1974	April 23	Oct 23	April 9, 1974
AF	1973	May 23	Oct 30	May 18, 1973
	1974	April 26	Oct 17	Nov 8, 1973

Measurement of treatment effects

Grain yield of corn was measured from the middle row of each subplot at the SIEF, WIEF, and CWEF sites. The harvest area consisted of 50 feet of 40-inch row. At the AF site grain yield was measured within a central harvest area of each plot equivalent to 70 feet of 30-inch row. The entire sample of ear corn was shelled and weighed at the CWEF and AF sites. At the SIEF and WIEF sites the sample of ear corn was weighed and a representative subsample was shelled for moisture determination. A subsample of the shelled corn was collected and stored pending measurement of moisture content. These subsamples were later weighed and dried at 70°C for a period of at least 3 days. The moisture content was calculated with an allowance for 3.0% moisture at the oven-dried weight. Grain yields were calculated on the basis of 15.5% moisture.

At the time of harvest, observations were also made on the number of barren, multiple-eared, root-lodged, and stalk-lodged plants in the harvest area. Plants leaning more than 30 degrees from the vertical but not broken below the ear were considered to be root lodged. Those broken below the ear were reported as stalk lodged. Lodging (or total lodging) is used as a collective term combining both the stalk and root lodged categories.

Each plot was soil sampled annually to measure the effect of K treatments on soil chemical properties with time. The soil samples consisted of 10-15 cores taken from a depth of 0-6 inches from the harvest area of each plot. All samples were analyzed for soil pH, buffer pH, available P, and exchangeable K.

The nutrient status of plants receiving the respective treatments was determined from the chemical analysis of leaf samples collected from plants in each plot when the corn was near the 75%-silking stage. The leaf opposite and just below the ear was removed from 20 plants in the harvest area within each plot. These samples were dried, weighed, finely ground through a stainless steel screen, stored in glass bottles, and later analyzed for total N, P, K, Ca, and Mg.

Stalk samples consisting of the first, second, and third elongated internodes above the brace roots were obtained from each treatment at the AF location in 1974. Ten stalks were selected at random within each treatment on five of the six replicates.

Length and diameter of the second internode and pith condition ratings of the first, second, and third internodes were determined on September 19 and 20, 1974. Stalk diameter and internode length were measured to the nearest 1.0 mm. Pith condition ratings were taken for three internodes by using a method developed by Pappelis (1957) in which the amount of dead parenchyma tissue in the pith served as an estimate of the percentage of cell death (senescence) in the stalk. The rating scale is as follows:

1. Up to 25 percent white tissue in the internode
2. 26 to 50 percent white tissue in the internode
3. 51 to 75 percent white tissue in the internode
4. 76 to 100 percent white tissue in the internode

Natural stalk rot symptoms and corn borer damage were recorded at the time pith conditions were rated. The stalks were rated as having symptoms if disintegration and (or) mycelial development was observed after the stalks had been split longitudinally and the interior of the nodes and internodes inspected.

Breaking strength measurements of the second internode were determined on September 23, 1974. Data from 10 plants for each treatment on five of the six replicates were taken. The breaking strength of the stalk at the middle of the second elongated internode above the ground level was determined by means of a specially constructed machine designed to apply a gradually increasing force against the stalk until breakage of the stalk occurred. The stalk to be tested was inserted in a sliding two-piece carriage and subjected to the gradually increasing lateral force. A spring scale simultaneously indicated the amount of force applied, and force required to break the stalk was read from a maximum value indicator on the scale. This force, recorded in pounds, was designated as stalk strength. A photographic illustration and a detailed description of the machine was given by Ikenberry (1964).

Laboratory Procedures

Leaf analysis for N, P, and K

Ground leaf samples were redried for approximately 24 hours at 65°C prior to analysis. Each sample was wet ashed by placing 0.5 g of plant material, 10 ml of concentrated H_2SO_4, and a small quantity of Cu catalyst in a 100 ml volumetric flask and heating the mixture on a hot plate until digestion was complete. The mixture was then cooled and diluted with NH_4-free distilled water to a volume of 100 ml. Aliquots of 5 ml were used for determinations of N, P, and K.

Total N content of plant samples was measured by a steam distillation procedure similar to that described by Bremner (1965). The sample solution was pipetted into a 200 ml distillation flask which was then attached to the steam-distillation apparatus. After addition of approximately 5 ml of 1N NaOH, steam was allowed to pass through the solution until approximately 30 ml of distillate collected in a 50 ml Erlenmeyer flask containing 5 ml of $H_3BO_3^-$ indicator solution. This solution was then titrated with standard 0.02N H_2SO_4.

Total P was determined by a colorimetric procedure involving vanado-molybdate solution (Hanway, 1962). Aliquots of sample solution (5 ml) and vanado-molybdate reqgent (25 ml) were added to 50 ml test tubes, and after allowing at least one-half hour for color development, the color intensity of the mixture was measured with a Klett-Summerson Photoelectric Colorimeter. Calibration curves were developed from standard solutions of KH_2PO_4.

The total K determination was made by adding 100 ml of lithium solution (104.1 ppm Li) to 5 ml of digestion solution. Percent K was then read directly from an IL 143 Flame Photometer. The calibration curve for the instrument was attained by repeated readings between samples with standard solutions made with KCl.

Leaf analysis for Ca and Mg

The digestion procedure consisted of nitric and perchloric acid digestion as described by Isaac and Kerber (1971). Ground leaf samples were redried for approximately 24 hours at 65°C prior to analysis. Plant samples weighing 0.2 g were initially digested in nitric acid. Perchloric acid was added later to insure complete digestion of all plant matter. Following the digestion, samples were diluted to 100 ml with deionized water and stored for analysis.

Prior to analysis the solutions were further diluted to bring cation concentrations into measurable ranges. The solutions were then analyzed using a Perkin-Elmer Model 303 Atomic Absorption Spectrophotometer. All samples and standards included 1% (w/v) lanthanum (La) added as a 5% solution of La_2O_3.

Standard solutions were prepared from Fisher Scientific Company Certified Atomic Absorption Standards. Samples were analyzed and plotted against standard curves to obtain percentage values for Ca and Mg.

Soil analysis

Soil samples to be analyzed for available P, exchangeable K, soil pH, and buffer pH were stored in a field-moist condition at a temperature of 1-2°C. These tests were carried out at the Iowa State University Soil Testing Laboratory on a slurry of 1:2 soil-water ratio made from each sample.

Available P was determined by extraction with Bray No. 1 solution (0.025N HCl and 0.03N NH_4F) and measurement of color intensity developed in a mixture of molybdate and soil-solution filtrate. Exchangeable K was determined by extraction with neutral, 1N NH_4OAc and analysis with an IL 143 Flame Photometer. Soil pH was measured at the soil-water ratio indicated above, and buffer pH was determined according to a method reported by Shoemaker et al., (1961).

Statistical Procedures

A preliminary analysis of variance was calculated for each experiment in order to determine overall treatment effects and replication differences.

A second degree polynomial was fitted to the data from each experiment for grain yield. The model used is as follows:

$$Y = b_o + b_1P + b_2P^2 + b_3K + b_4K^2 + b_5PK + e,$$

where Y, P, and K are grain yield, coded plant population level, and coded K fertilizer rate, respectively. The b's are the partial regression coefficients and e is a random error component. No attempt was made to delete terms from the equation on the basis of statistical significance. The fitting of these equations to each site-year (each location in each year) of data gives some indication as to the response at that location.

An estimation of the plant population and K fertilizer rate required for maximum yield was made from these equations.

Applied potassium was coded as follows for regression analysis:

$$1 \text{ unit potassium} = \frac{K}{50} + 1.$$

At the CWEF, SIEF, and AF sites plant population was coded as follows:

$$1 \text{ unit population} = \frac{P}{10{,}000}.$$

At the WIEF site plant population was coded as follows:

$$1 \text{ unit population} = \frac{P}{8{,}000}.$$

An exponential equation was fitted to each site-year of data for grain yield per plant. The model used is as follows:

$$y = c\,10^{bP} \text{ or } \log y = \text{Log } c + bP$$

where y is the yield per plant, c is a constant, b is the slope of the regression line, and P is the coded plant population level. An estimation of the plant population producing maximum yield was made from these equations.

An exponential equation was fitted to the lodging data from each experiment. The formula for the relationship is as follows:

$$L = c\ 10^{bK}$$

where L is the percent lodging at a given population level, c is a constant, b is the slope of the regression line, and K is the coded potassium fertilizer rate.

RESULTS AND DISCUSSION

Corn Yield

This section includes analysis of yield results for each site-year of data. Grain yields for individual plots are shown for each experiment and each year in Table 30 (Appendix). Mean yields for each treatment are shown in Table 3. An analysis of variance was calculated in order to determine overall treatment effects (Table 4). Potassium fertilizer treatments significantly affected yields in 8 of the 9 site-years. The nonsignificant effect of K in 1974 at the WIEF site may have been due to low yields resulting from dry weather. Plant population significantly affected yields in each site-year. Significant block differences were found at the CWEF site in 1972 and at the AF site in 1974. Exchangeable K varied significantly between blocks and was the soil variable most highly correlated with yields at the CWEF site in 1972. Following heavy spring rains in 1974, N deficiency symptoms were observed on 2 of the 6 blocks at the AF site. These blocks had significantly lower yields and lower percent leaf N than the blocks which did not show N deficiency symptoms.

A significant population by K interaction was observed at the AF site in 1973. The yield response to K varied with plant population. Potassium fertilization had no effect on yields at the 10,000 plant per acre stand but significantly affected yields at the high stand levels.

In 1972 yields were excellent at all locations, reaching 167.2, 159.3, and 136.3 bushels at the SIEF, WIEF, and CWEF sites, respectively.

Table 3. Mean grain yield per acre, number of ears per plant, and grain yield per plant for the respective K and plant population treatments at individual sites in each year

K rate lb/A	Population 1000 plants/A	Grain yield, bu/A at 15.5% moisture			Ears/plant			Grain yield, lb/plant		
		1972	1973	1974	1972	1973	1974	1972	1973	1974
					CWEF					
0	10	98.4	101.5	86.0	1.90	1.56	1.18	0.54	0.58	0.48
	20	123.1	139.2	103.3	1.21	1.01	1.00	0.35	0.38	0.30
	30	121.7	131.8	103.5	1.03	0.96	0.99	0.24	0.25	0.21
	40	118.4	118.5	82.8	0.94	0.93	0.90	0.17	0.18	0.13
50	10	103.0	107.9	92.7	1.92	1.58	1.30	0.60	0.60	0.52
	20	128.8	133.2	112.7	1.20	1.00	0.99	0.36	0.37	0.32
	30	128.1	134.2	116.0	1.01	0.98	0.99	0.24	0.26	0.23
	40	120.0	122.8	88.7	0.94	0.92	0.89	0.17	0.19	0.14
200	10	112.3	106.9	97.5	1.93	1.56	1.22	0.63	0.59	0.54
	20	134.3	131.7	118.3	1.27	1.02	1.00	0.38	0.38	0.34
	30	136.3	148.1	107.4	1.01	0.97	0.97	0.26	0.28	0.21
	40	130.7	129.8	96.6	0.93	0.93	0.91	0.19	0.20	0.15
					WIEF					
0	8	97.2	102.4	87.6	1.95	1.96	1.23	0.69	0.70	0.61
	16	131.1	130.5	90.8	1.24	1.22	0.90	0.48	0.46	0.30
	24	146.0	133.9	64.6	0.99	0.98	0.60	0.34	0.31	0.15
	32	142.9	128.8	41.0	0.95	0.94	0.37	0.26	0.24	0.07

Table 3. (Continued)

K rate lb/A	Population 1000 plants/A	Grain yield, bu/A at 15.5% moisture 1972	1973	1974	Ears/plant 1972	1973	1974	Grain yield, lb/plant 1972	1973	1974
50	8	101.9	108.4	85.9	1.96	1.97	1.18	0.71	0.73	0.61
	16	144.2	130.8	83.6	1.22	1.25	0.86	0.51	0.48	0.28
	24	152.4	136.8	56.9	1.01	0.98	0.62	0.36	0.33	0.14
	32	148.0	137.4	39.9	0.98	0.96	0.37	0.26	0.25	0.07
200	8	103.2	108.6	91.3	1.90	1.99	1.32	0.72	0.77	0.63
	16	141.4	135.3	94.8	1.22	1.21	0.89	0.50	0.48	0.33
	24	158.4	146.6	68.5	1.02	0.99	0.66	0.38	0.34	0.17
	32	159.3	136.2	38.4	0.96	0.96	0.32	0.29	0.25	0.07
				SIEF						
0	10	102.4			1.84			0.60		
	20	122.6			1.05			0.35		
	30	138.2			0.91			0.27		
	40	133.7			0.79			0.19		
50	10	107.9			1.81			0.64		
	20	144.6			1.06			0.42		
	30	159.5			0.97			0.31		
	40	149.4			0.91			0.21		
200	10	113.5			1.81			0.67		
	20	157.1			1.07			0.44		
	30	167.2			0.98			0.32		
	40	152.7			0.94			0.22		

Table 3. (Continued)

K rate lb/A	Population 1000 plants/A	Grain yield, bu/A at 15.5% moisture 1972	1973	1974	Ears/plant 1972	1973	1974	Grain yield, lb/plant 1972	1973	1974
				AF						
0	10		96.5	101.3		1.63	1.30		0.55	0.56
	20		111.6	138.3		0.97	1.00		0.32	0.39
	30		106.7	143.3		0.87	0.98		0.20	0.26
	40		81.4	124.9		0.65	0.93		0.12	0.18
50	10		98.2	99.1		1.53	1.19		0.54	0.54
	20		117.9	132.2		1.00	1.00		0.34	0.37
	30		109.2	140.9		0.86	0.97		0.21	0.26
	40		97.2	134.1		0.75	0.93		0.14	0.19
100	10		99.5	101.6		1.57	1.21		0.56	0.56
	20		127.2	140.5		1.00	0.99		0.36	0.40
	30		118.0	145.7		0.90	0.98		0.23	0.25
	40		99.9	146.7		0.77	0.96		0.15	0.21
200	10		94.2	101.9		1.47	1.32		0.53	0.57
	20		125.2	147.4		0.99	1.00		0.36	0.41
	30		111.3	153.0		0.86	0.98		0.21	0.28
	40		112.7	147.1		0.80	0.95		0.17	0.21

Table 4. Analysis of variance of corn yield for the respective K and plant population treatments at individual sites in each year

Source of Variation	Degrees of freedom	Mean squares 1972	1973	1974
		CWEF		
Blocks	5	113.47++	140.41	104.82
Potassium treatments (K)	2	1045.86**	258.89++	804.46**
Error (a)	10	34.82	100.21	54.65
Population-treatments (P)	3	2360.43**	3887.93**	2326.32**
P X K	6	11.76	189.00	89.96
Error (b)	45	25.58	102.77	78.30
		WIEF		
Blocks	5	99.61	159.88	724.50
Potassium treatments (K)	2	779.18*	364.16++	295.72
Error (a)	10	124.77	95.59	353.40

**Denotes 1% level of significance.

*Denotes 5% level of significance.

++Denotes 10% level of significance.

Table 4. (Continued)

Source of variation	Degrees of freedom	Mean squares 1972	1973	1974
Population-treatments (P)	3	10246.91**	3855.10**	10160.08**
P X K	6	71.24	49.62	65.37
Error (b)	45	60.55	54.26	177.46
		SIEF		
Blocks	5	72.51		
Potassium treatments (K)	2	3444.48**		
Error (a)	10	76.29		
Population-treatments (P)	3	7532.64**		
P X K	6	181.76		
Error (b)	45	160.84		
		AF		
Blocks	5		140.28	548.66*
Potassium treatments (K)	3		768.57*	663.31*
Error (a)	15		159.39	148.06

Table 4. (Continued)

Source of variation	Degrees of freedom	Mean squares 1972	1973	1974
Population-treatments (P)	3		3057.34**	9947.99**
P X K	9		232.22**	144.99
Error (b)	60		80.38	88.60

limiting rainfall during August may have contributed to the lower yields at the CWEF site. Yields in some of the other experiments on the same farm reached 150 bushels or more, however. Wet spring weather delayed planting in 1973 at all locations and most likely caused yield reductions. Dry weather during July and August and hail damage on the 8th of July further reduced yields at the CWEF site. A heavy infestation of rootworm beetles at the silking stage most likely caused yield reductions at the WIEF site. The 1974 season was characterized by hot, dry weather in many sections of Iowa. Yields at the CWEF and WIEF sites were considerably below the 1972-1973 averages. On July 16, approximately 1 inch of supplemental water was applied to the experimental plots at the AF site by means of sprinkler irrigation. Yields at this site reached 150 bushels per acre.

In nearly all of the experiments, responses to K fertilization continued up to the top rate of 200 pounds of K per acre. Maximum responses were in the 12 and 15-bushel range at the CWEF, AF, and WIEF sites, all of which tested low in K. On the very low testing SIEF site, responses reached approximately 30 bushels. Responses to K fertilization were generally largest at the plant populations supporting the higher yields. At the AF site in 1973 a 32 bushel response was obtained at the highest plant population. Yields were exceedingly low at this population, however.

In all of the experiments, the lowest population of 8,000 or 10,000 plants per acre was inadequate for top yields. Yields at the higher populations varied with year and site. Generally the intermediate stands of 20,000 or 30,000 plants per acre were the most effective. The superior performance of the low stands at the WIEF site in 1974 was a reflection of the hot, dry conditions which prevailed in midsummer in much of western Iowa.

In order to ascertain more fully the effect of K fertilization and stand level on corn yields, multiple regression analysis of the data were made for each site-year of data by fitting the following general model:

$$Y = b_0 + b_1P + b_2P^2 + b_3K + b_4K^2 + b_5PK + e$$

where Y, P, K, the b's, and e have the meaning already described in the statistical procedures section. Stands were coded at values of 1, 2, 3, and 4. Potassium fertilization rates were coded at values of 1, 2, 3, and 5. The partial regression coefficients for linear, quadratic, and linear by linear interactions with their significance level and the R^2-value for each site-year of data are given in Table 5.

Discussion of the effects of applied K and plant population on yield involves considering the significance and sign of the partial regression coefficients. The level of significance of each regression coefficient refers to the probability of obtaining a t value as high as, or higher than, that obtained experimentally when a random sample is taken from a homogeneous population. However, coefficients which do not reach significance at the established limit of 10 percent might still have biological meaning.

Table 5. Regression coefficients, their significance level, and the R^2-value from fitting a regression equation to corn yields on each site-year of data

Variable	1972	1973	1974	1972	1973	1974
		CWEF			WIEF	
b_0	58.942	59.143	34.437	34.644	58.419	86.488
b_1	42.744**	57.365**	48.084**	63.985**	46.796**	15.982^{++}
b_2	- 7.453**	-10.894**	- 9.761**	-10.075**	- 7.685**	- 6.347**
b_3	5.875^{++}	- 0.777	14.746**	9.442*	6.392	- 8.137
b_4	- 0.447	- .064	- 1.947*	- 1.496*	- 0.838	1.688
b_5	0.025	1.101^{++}	- 0.124	0.937^{++}	0.230	- 0.547
R^2	.783	.633	.625	.875	.730	.649

**Denotes 1% level of significance.

*Denotes 5% level of significance.

$^{++}$Denotes 10% level of significance.

Table 5. (Continued)

Variable	1972	1973	1974	1972	1973	1974
		SIEF			AF	
b_0	17.616				58.995	46.594
b_1	65.862**				39.470**	65.261**
b_2	-10.300**				- 9.218**	-11.545**
b_3	25.729**				6.399	- 0.948
b_4	- 3.421**				- 1.461*	- 0.001
b_5	0.261				2.150**	1.539*
R^2	.757				.546	.732

Individual R^2-values varied from .546 to .872. The response to plant population was significant for all site-years of data. The significant negative quadratic coefficients indicate in all cases decreasing returns at higher plant population levels.

The response to K fertilization varied considerably among sites and years. The relative magnitude and significance of the linear, quadratic, and interaction terms were erratic although in all cases decreasing returns at higher rates of K application were observed.

The K rate by plant population interaction did not show any consistent trends over years, either in magnitude and/or sign of the regression coefficients.

The K rate and stand level required for the maximum yield was obtained by equating the first partial derivative of yield with respect to each variable at zero and solving the resulting equations simultaneously. Substitution of these rates in the prediction equation results in the estimated maximum yield. In 1972 and 1973 at the CWEF site and in 1974 at the AF site the predicted maximum yield was outside the range of experimental rates. Under these conditions, the limit of K application (200 pounds per acre) was selected for prediction.

Table 6 summarizes the rates of K fertilization and plant population level that would have given maximum yield of corn each year within the range of experimental rates. The predicted maximum yields are also given in Table 6.

The yield isoquants presented in Figures 1 through 9 illustrate the effects of potassium fertilization and plant population level on yields.

Table 6. Plant populations and K fertilizer rates that would have given maximum yields of corn within the range of experimental rates used and the predicted maximum yield for each site-year of data

Site	Year	lb K/A	Plants/A	Yield (Bu/A)
CWEF	1972	200	28,700	139
	1973	200	28,800	144
	1974	135	24,400	120
SIEF	1972	144	31,000	169
WIEF	1972	159	26,200	162
	1973	162	24,900	145
	1974	80	9,200	85
AF	1973	155	26,200	124
	1974	200	31,600	157

Responses to K fertilization were generally largest at the plant populations supporting the higher yields. At low population levels the response to K was at a minimum as indicated by the horizontal nature of the yield isoquants. At the low plant populations the individual plants approached or reached a genetic limit in grain production and responded less to K fertilization than plants at the higher stand levels.

In order to characterize the effect of plant population on the average yield of individual plants, the following equation was fitted to each site-year of data:

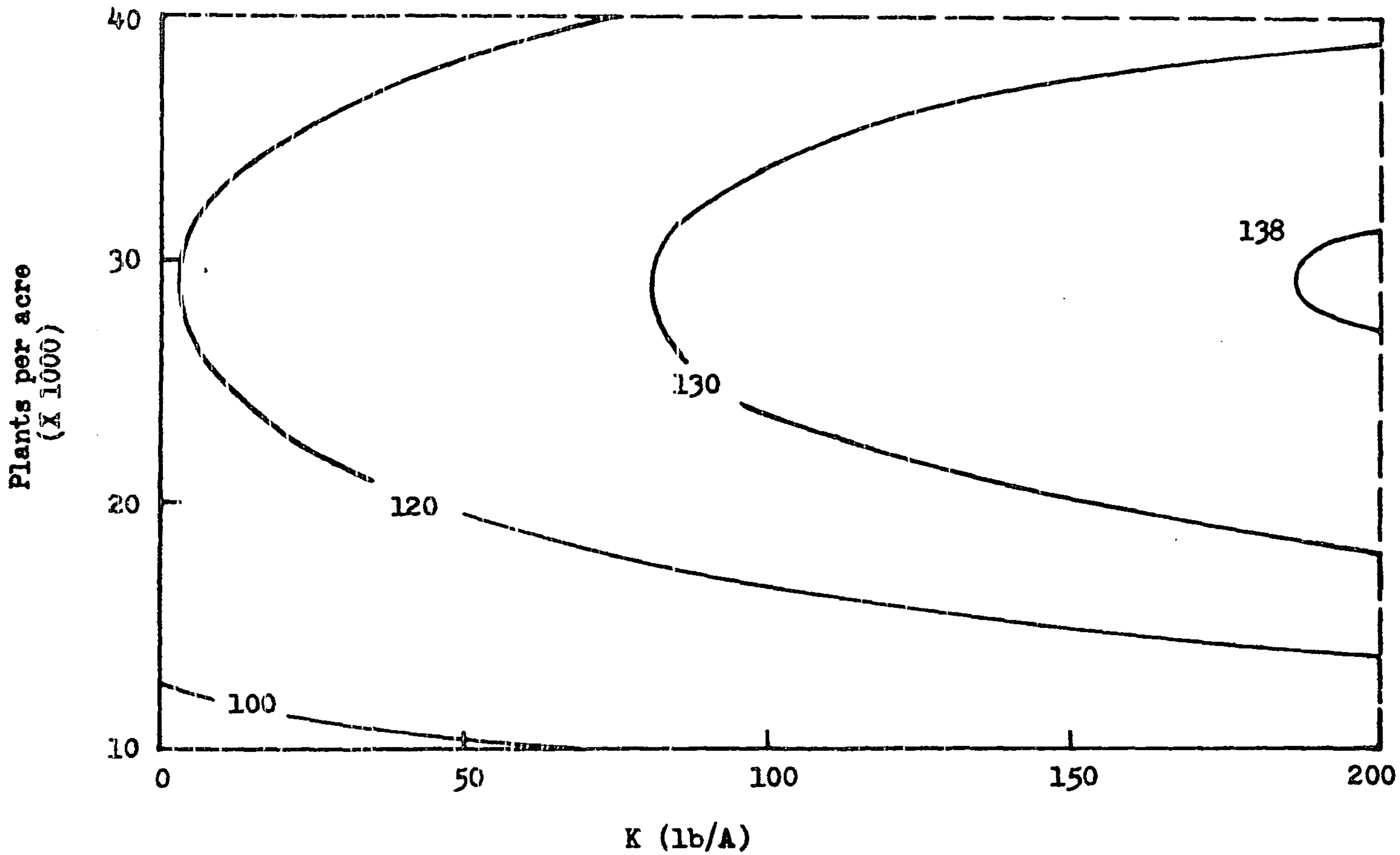

Figure 1. Yield isoquants derived from the prediction equation for corn yield at the CWSF site in 1972

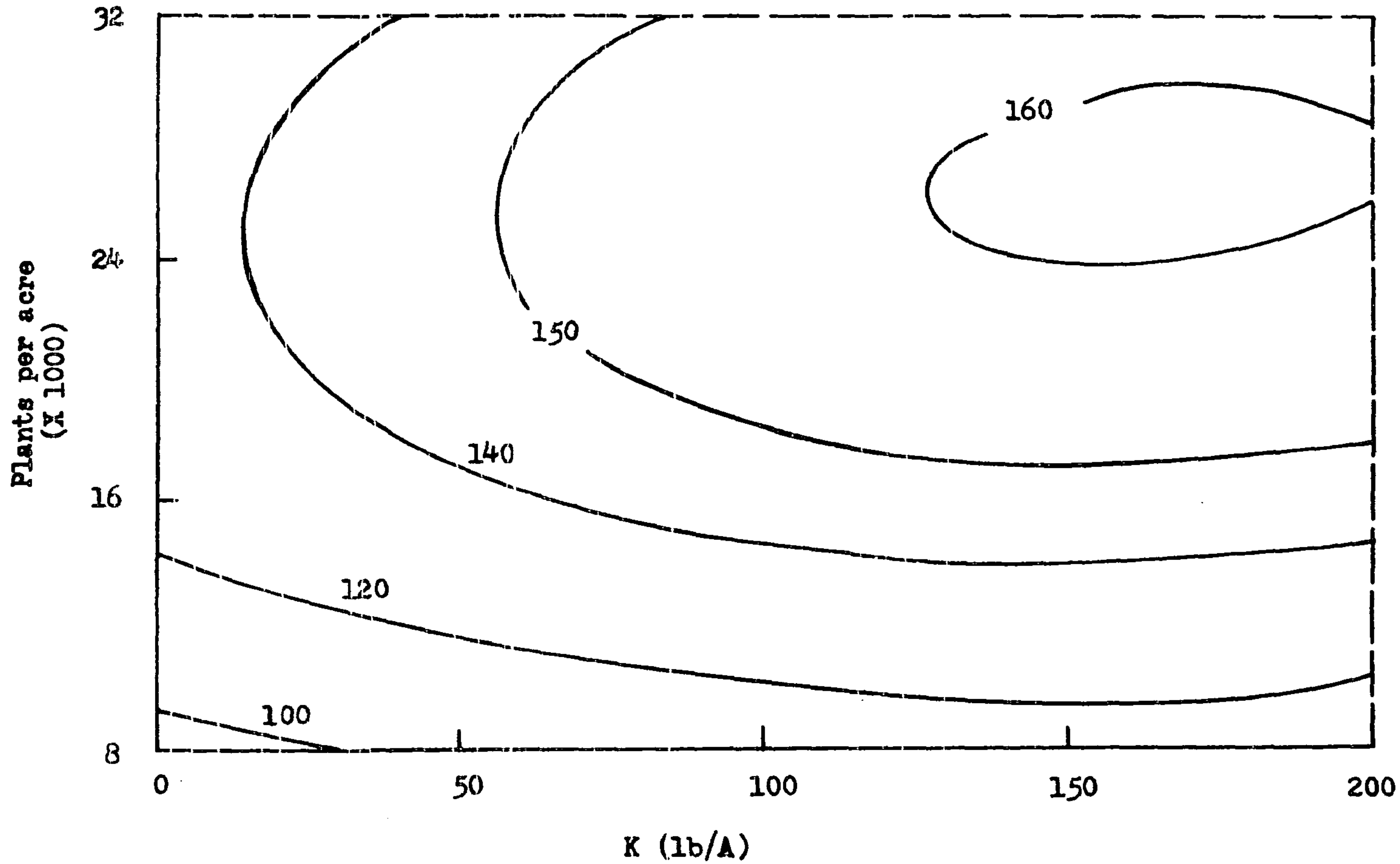

Figure 2. Yield isoquants derived from the prediction equation for corn yield at the WIEF site in 1972

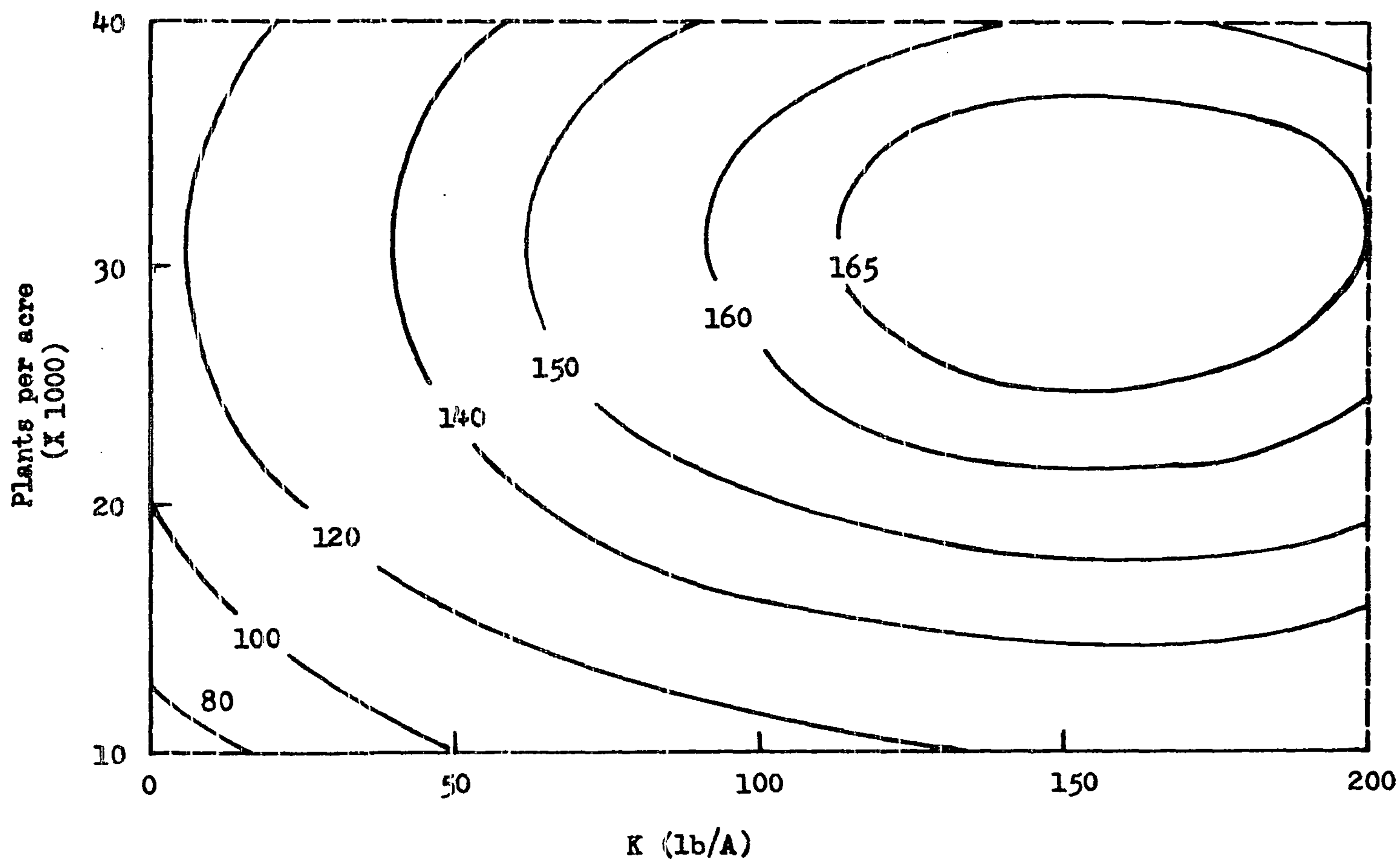

Figure 3. Yield isoquants derived from the prediction equation for corn yield at the SIEF site in 1972

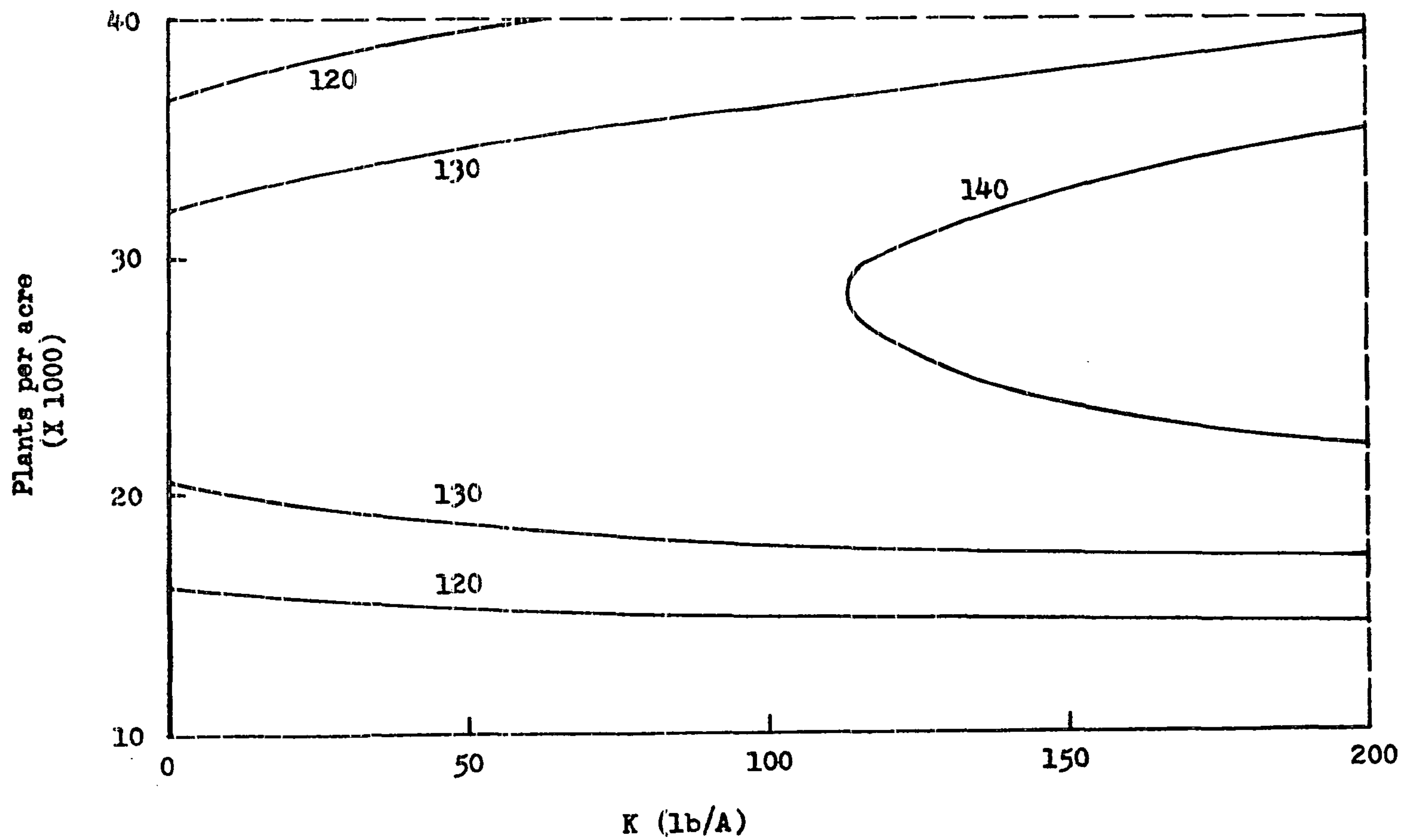

Figure 4. Yield isoquants derived from the prediction equation for corn yield at the CWEF site in 1973

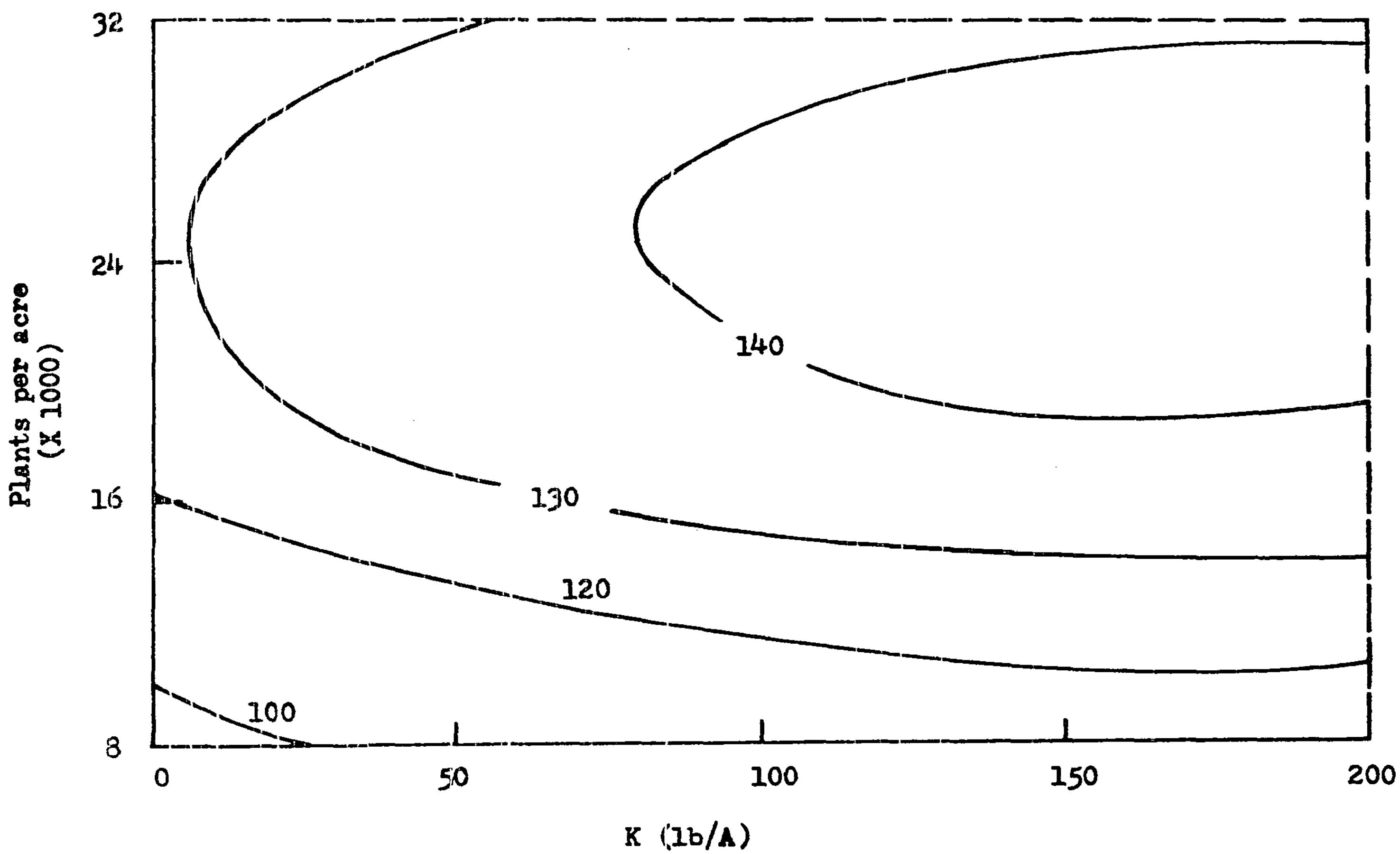

Figure 5. Yield isoquants derived from the prediction equation for corn yield at the WIEF site in 1973

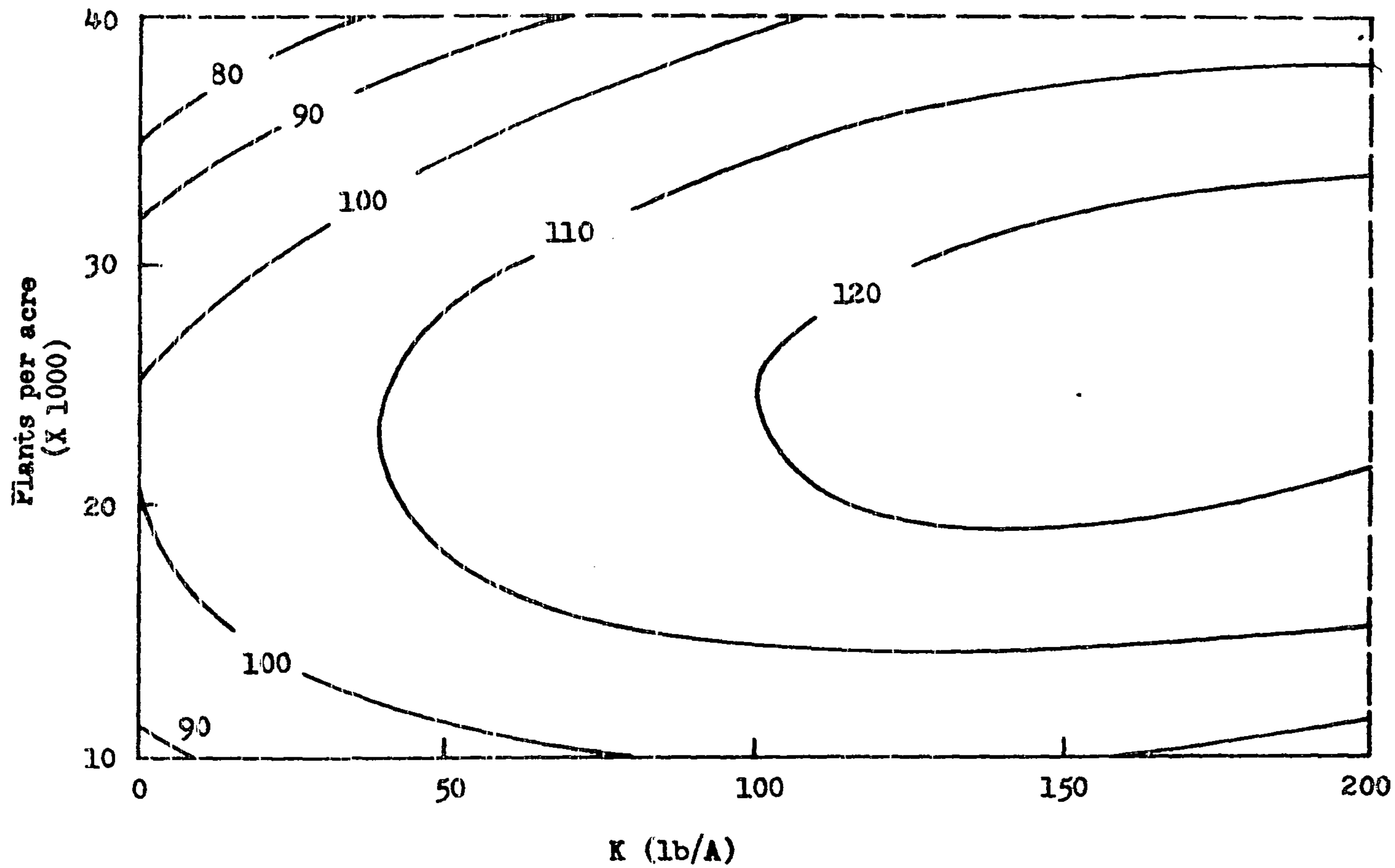

Figure 6. Yield isoquants derived from the prediction equation for corn yield at the AF site in 1973

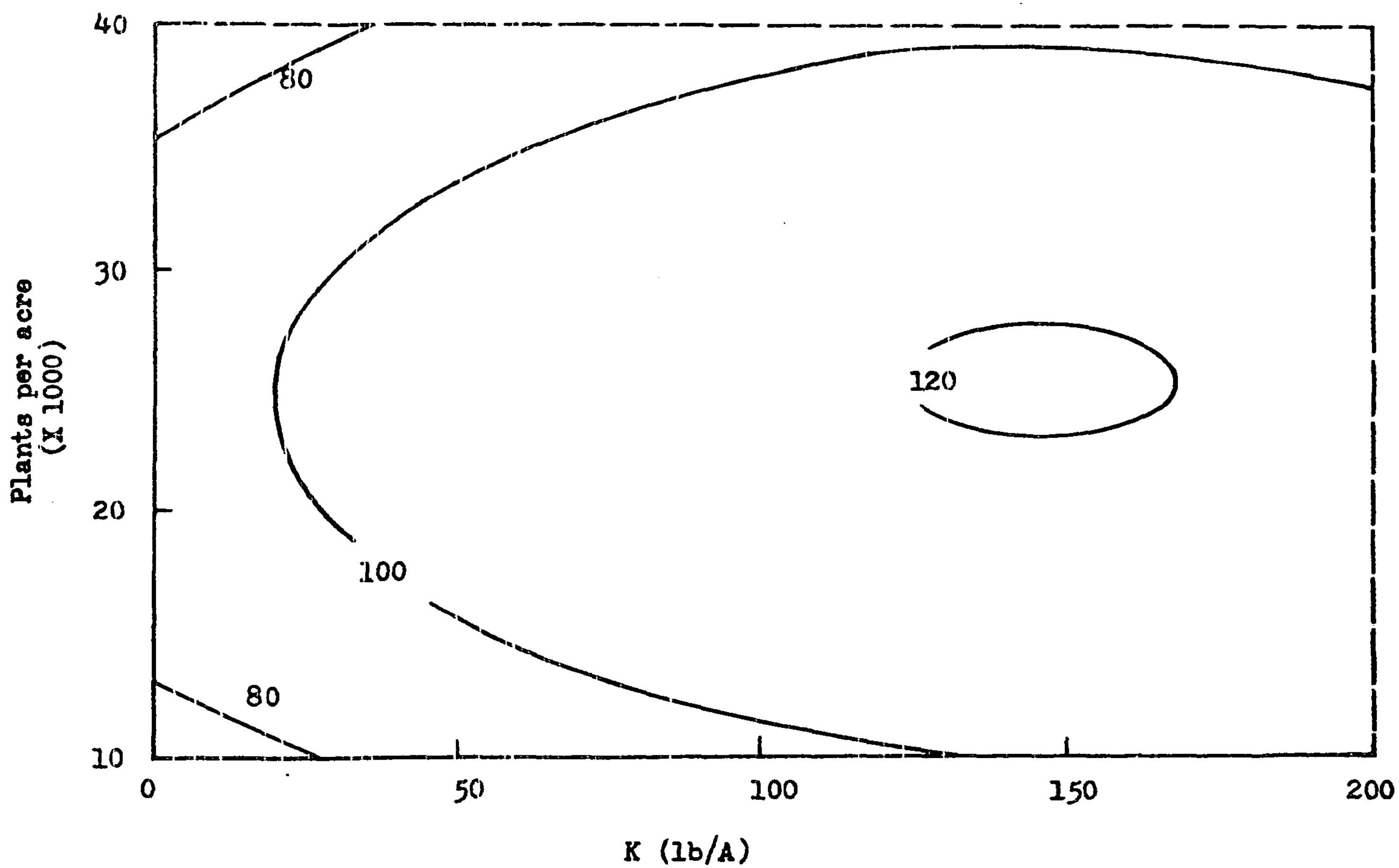

Figure 7. Yield isoquants derived from the prediction equation for corn yield at the CWEF site in 1974

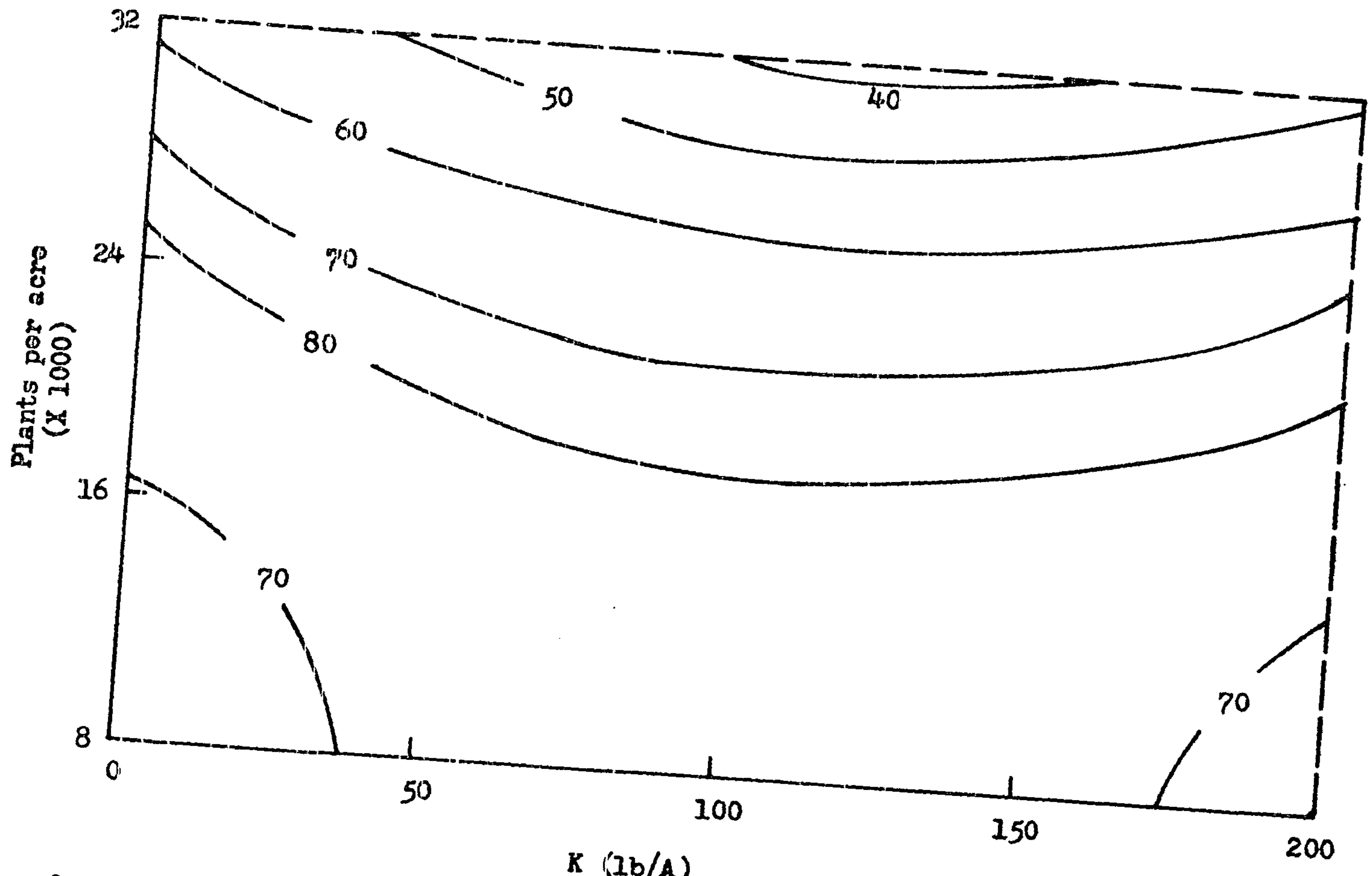

Figure 8. Yield isoquants derived from the prediction equation for corn yield at the WIEF site in 1974

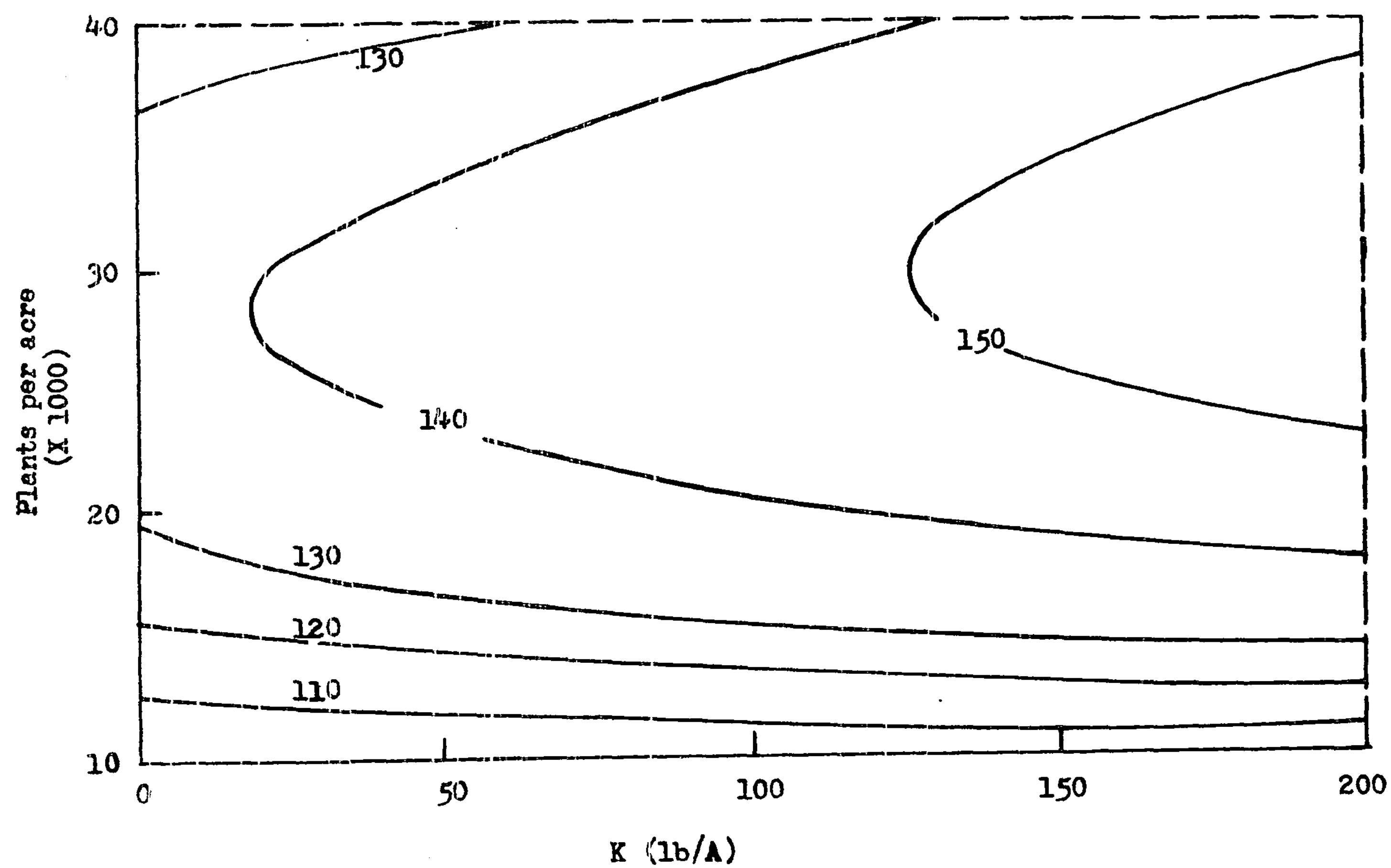

Figure 9. Yield isoquants derived from the prediction equation for corn yield at the AF site in 1974

$$\text{Log } y = \text{Log } c + bP$$

where y, c, b, and P have the meaning already indicated in the statistical procedures section. When the linear graph of the logarithm of yield per plant is converted to the usual graph of yield per acre against the population, the straight line with the steeper (more negative) slope corresponds to the corn that gives its maximum yield at the lower population.

The partial regression coefficient for the linear effect of plant stand level, the significance level, and the R^2-value for each experiment are given in Table 7. Individual R^2-values varied from .874 to .970. The high R^2-values are evidence that within the range of populations studied the relationship between the logarithm of the average yield per plant and the population is essentially linear. The relationships are shown in Figures 10 through 13 for each location. The slopes of the regression lines indicate that the plant population giving maximum yield at the CWEF site was at a maximum in 1973 and at a minimum in 1974. This is in agreement with the population levels for maximum yield already presented in Table 6. The slopes of the regression lines for the WIEF and AF sites are also in agreement with the plant populations required for maximum yields given in Table 6.

It has been shown that increasing the N level in the soil increases the number of plants needed for maximum yield. The effect of increasing N levels in the soil is to change the slope of the regression line. In order to determine if K fertilization has a similar effect, individual

Table 7. Regression coefficents, their significance level, and the R^2-value from fitting a regression equation to grain yield per plant on each site-year of data

Variable	CWEF 1972	CWEF 1973	CWEF 1974	WIEF 1972	WIEF 1973	WIEF 1974	SIEF 1972	AF 1973	AF 1974
Log K	-.0773	-.0777	-.1046	-.0176	-.0071	-.1214	-.0547	-0.710	-.1057
b	-.1718**	-.1633**	-.1908**	-.1390**	-.1588**	-.3259**	-.1589**	-.1966**	-.1530**
R^2	.970	.957	.961	.964	.963	.874	.923	.947	.935

**Denotes 1% level of significance.

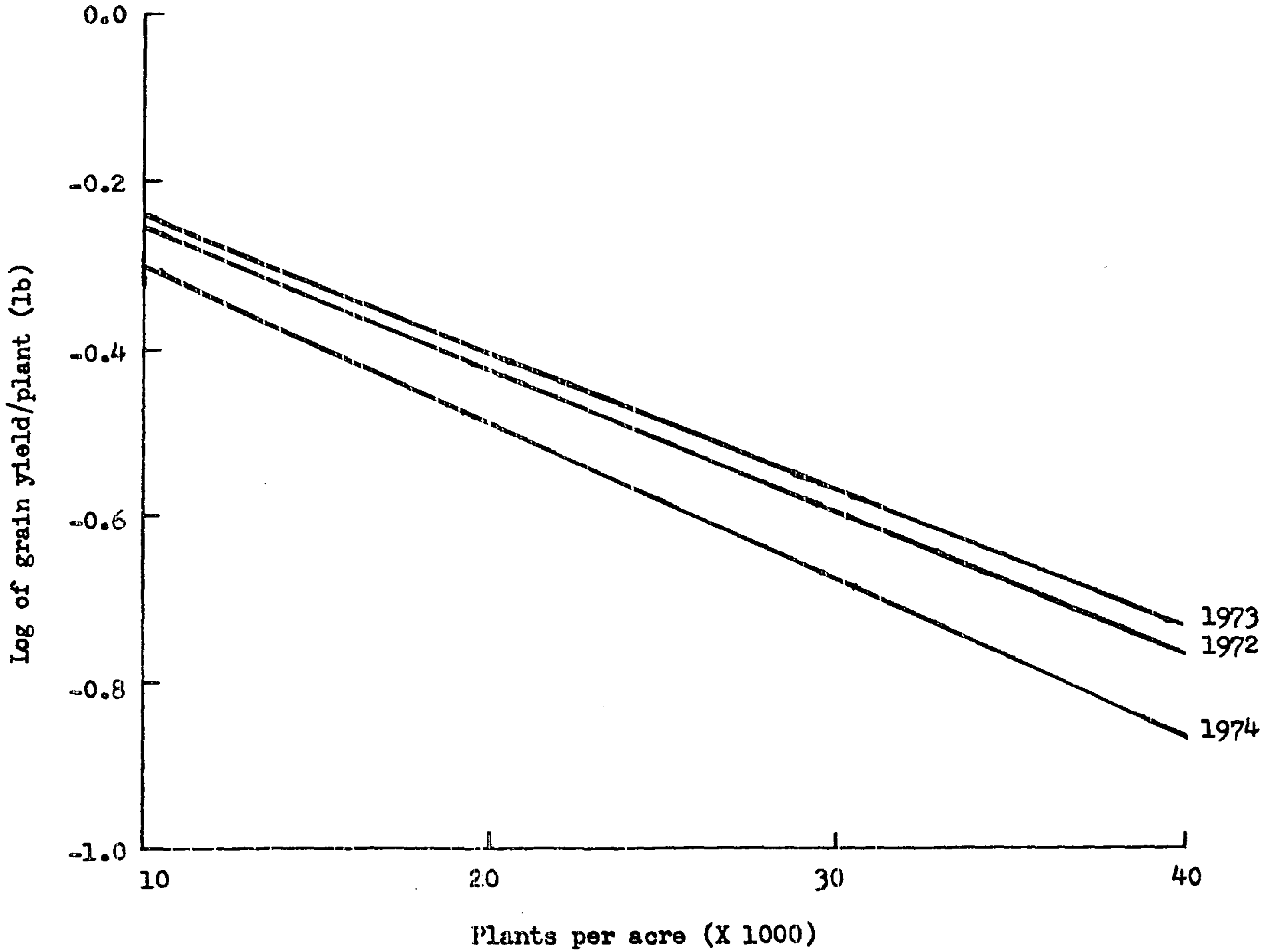

Figure 10. The logarithm of grain yield per plant as influenced by plant population at the CWEF site

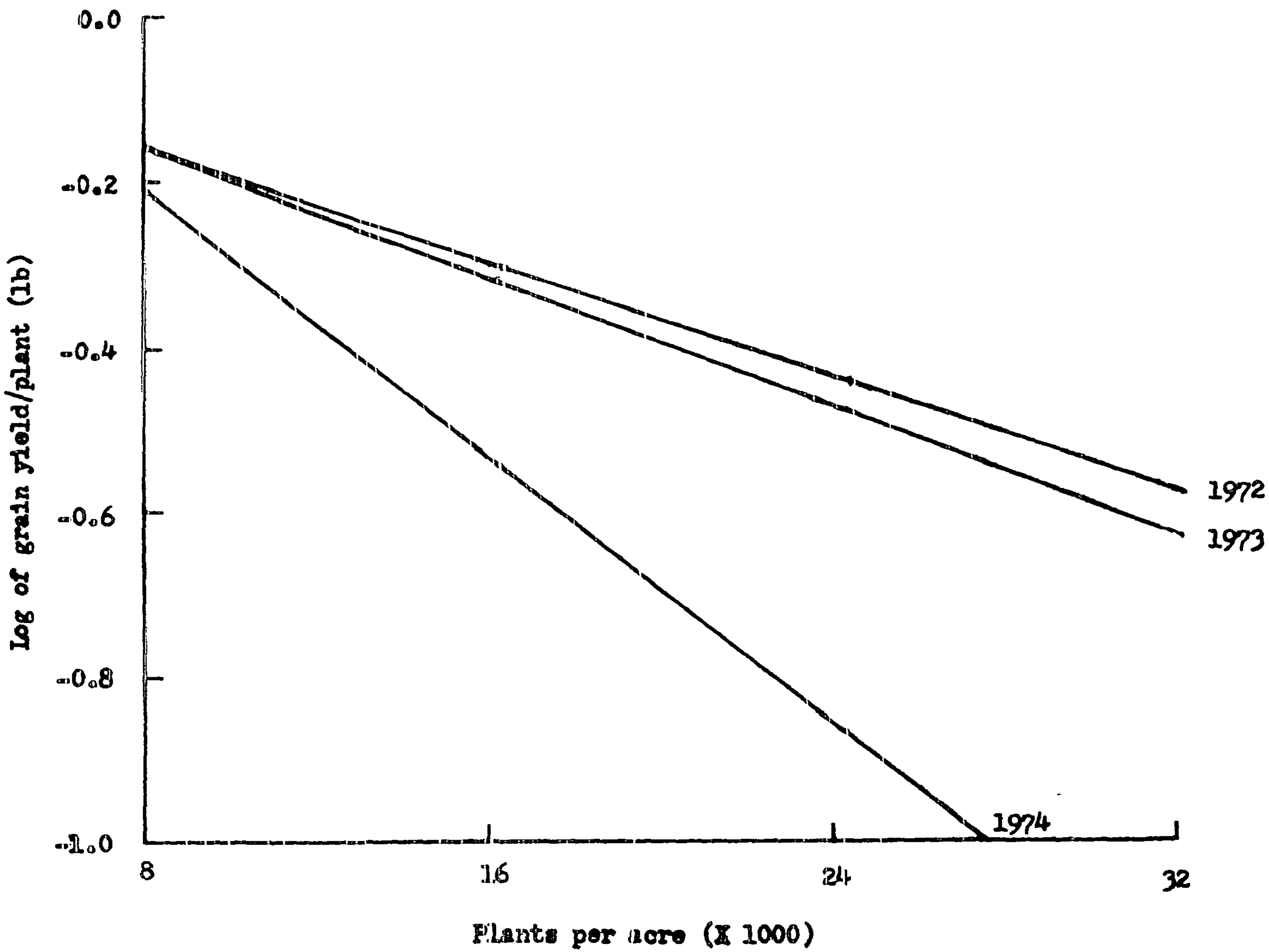

Figure 11. The logarithm of grain yield per plant as influenced by plant population at the WIEF site

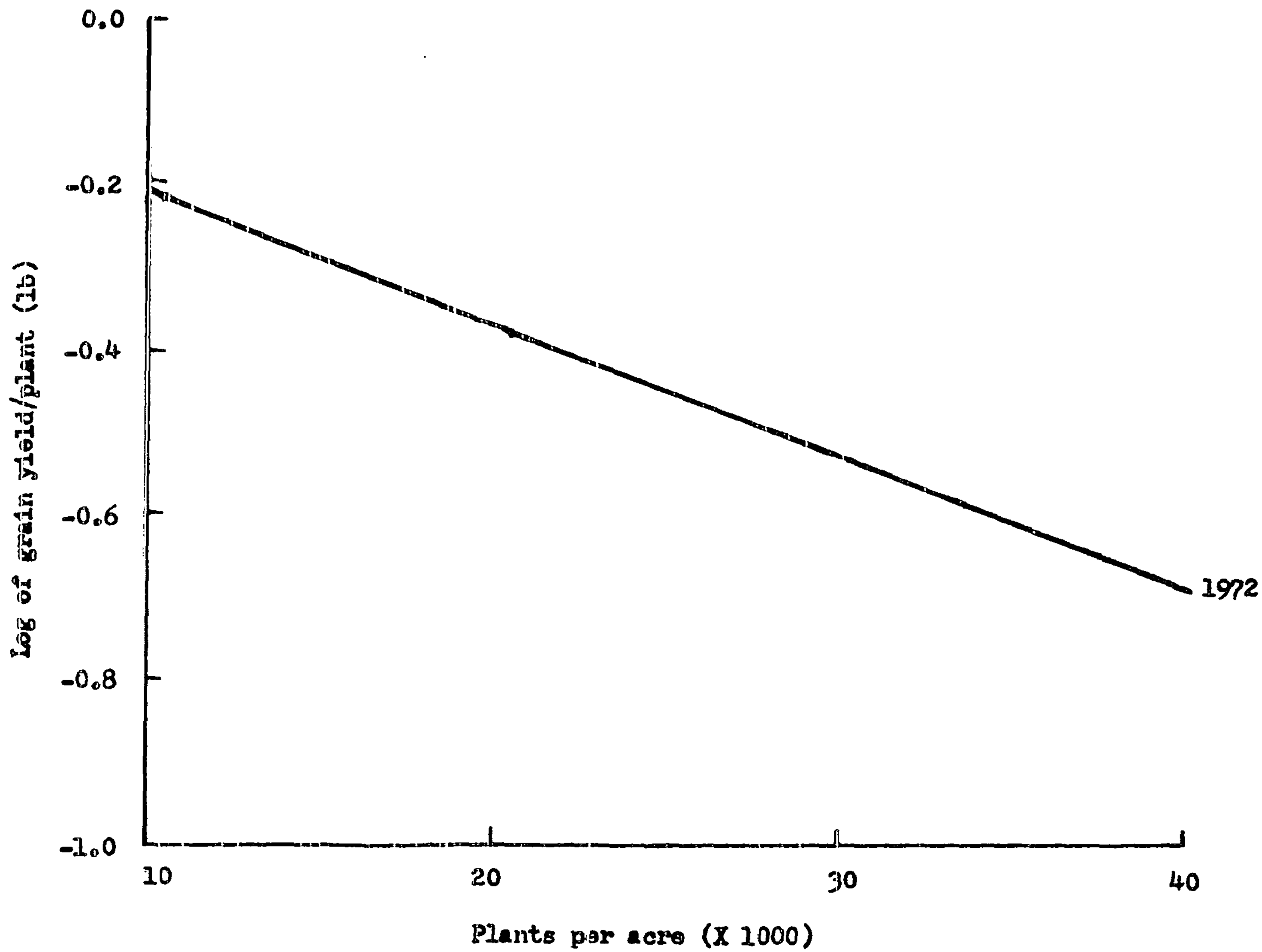

Figure 12. The logarithm of grain yield per plant as influenced by plant population at the SIEF site

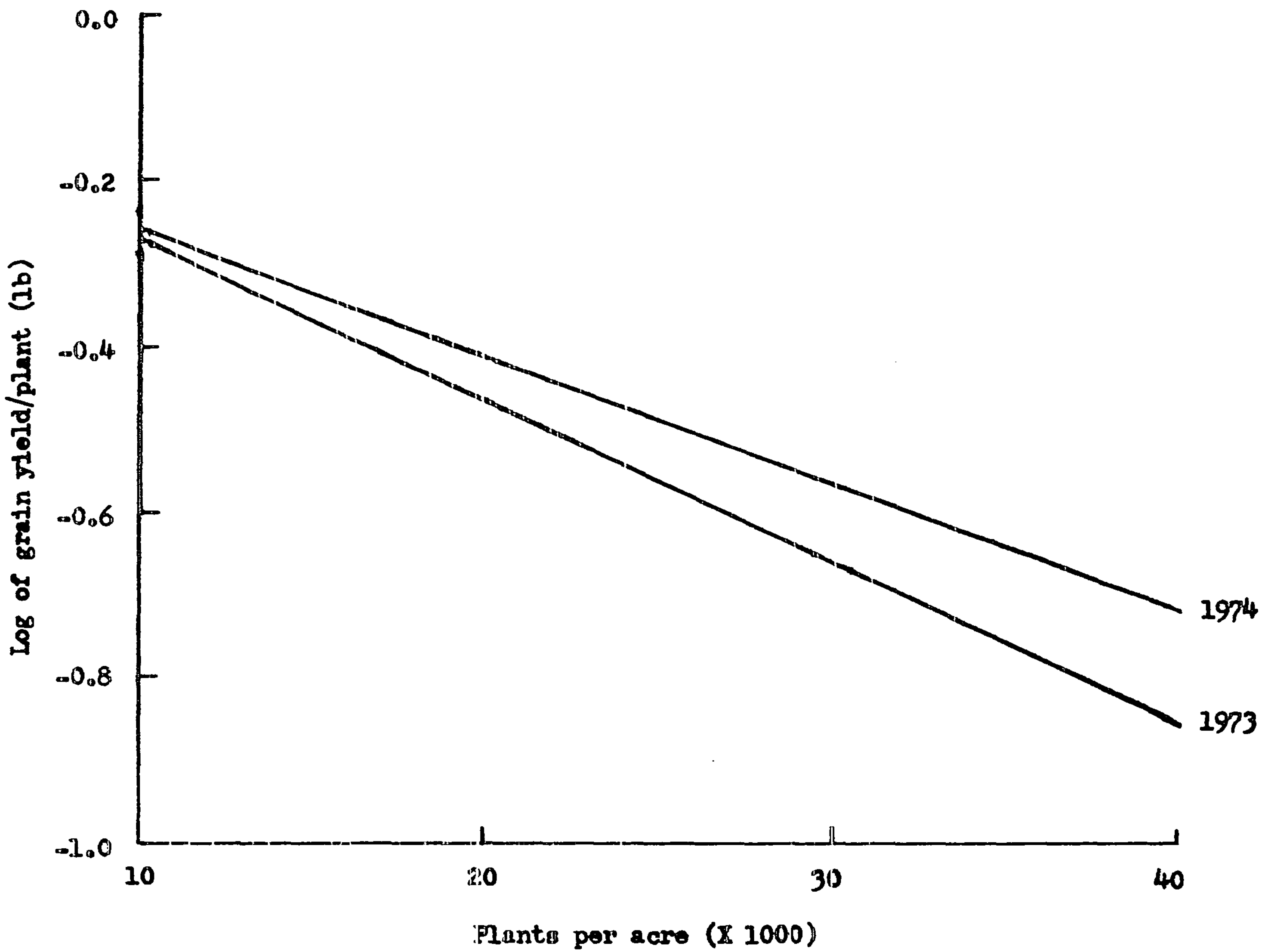

Figure 13. The logarithm of grain yield per plant as influenced by plant population at the AF site

regression equations were fitted to the data for each K rate and the slopes of the regression lines were then compared.

Table 8 contains the partial regression coefficient for the linear effect of plant population, the significance level, and the R^2-value for each site-year of data. In 4 of the 9 site-years of data the number of plants needed for maximum yields were increased by K fertilization as indicated by b_1 values. The b_1 values increased (became less negative) as K rates increased. In the remaining site-years the number of plants needed for maximum yields decreased or remained approximately the same as K fertilizer rates were increased. Because of the inconsistent response it is difficult to determine the true effect of different K levels on the plant population needed for maximum yields. It may be that the effect of K would be to increase yields at all populations proportionately and thus not significantly affect the population needed for maximum yield. The nonsignificant population by K interation in 8 of the 9 site-years of data substantiates this speculation.

Multiple-eared and Barren Plants

The percentage of plants having multiple-ears in 1972 and 1973 at each location are given in Table 9. An analysis of variance was calculated to determine overall treatment effects (Table 10). The number of plants having multiple-ears was controlled entirely by plant population except for the significant effect of K fertilization in 1972 at the GWEF site. At the lower plant populations of 8- and 10,000 plants per acre from 47 to 99 percent of the plants had two or more ears. The

Table 8. Regression coefficients, their significance level, and the R^2-value from fitting a regression equation to grain yield per plant on each site-year of data

Variable	CWEF 1972	CWEF 1973	CWEF 1974	WIEF 1972	WIEF 1973	WIEF 1974	SIEF 1972	AF 1973	AF 1974
					0 lb K/A				
Log K	-.1187	-.0635	-.1343	-.0266	-.0092	.1144	-.0931	-.0456	-.0855
b_1	-.1630**	-.1749**	-.1888**	-.1412**	-.1590**	-.3261**	-.1603**	-.2208**	-.1649**
R^2	.983	.960	.975	.954	.966	.827	.904	.955	.964
					50 lb K/A				
Log K	-.0623	-.0761	-.0961	-.0026	-.0011	.0878	-.0503	-.0803	-.1248
b_1	-.1791**	-.1638**	-.1906**	-.1443**	-.1533**	-.3165**	-.1563**	-.1939**	-.1524**
R^2	.978	.978	.963	.978	.960	.942	.977	.980	.899
					100 lb K/A				
Log K								-.0561	-.1149
b_1								-.1952**	-.1470**
R^2								.978	.941
					200 lb K/A				
Log K	-.0511	-.0936	-.0834	-.0238	.0316	.1621	-.0206	-.1021	-.0977
b_1	-.1732**	-.1514**	-.1930**	-.1316**	-.1640**	-.3350**	-.1601**	-.1766**	-.1476**
R^2	.976	.952	.965	.980	.976	.868	.973	.934	.975

**Denotes 1% level of significance.

Table 9. Percent multiple-eared corn plants for the respective K and population treatments at individual sites in each year

K rate lb/A	Population 1000 plants/A[a]	CWEF 1972	CWEF 1973	CWEF 1974	WIEF 1972	WIEF 1973	WIEF 1974	SIEF 1972	AF 1973	AF 1974
0	10	90.2	56.3		95.0	95.9		85.2	62.7	
	20	20.9	1.1		24.1	22.7		8.5	8.7	
	30	4.8	0.0		0.9	0.5		0.9	0.1	
	40	1.5	0.0		0.0	0.1		0.1	0.1	
50	10	91.6	57.7		95.8	96.7		81.4	58.3	
	20	21.0	0.2		22.1	25.7		7.4	2.2	
	30	4.3	0.3		2.8	2.0		0.9	0.0	
	40	1.7	0.0		0.7	0.3		0.0	0.0	
100	10								56.9	
	20								2.3	
	30								0.0	
	40								0.0	
200	10	93.5	55.7		90.3	99.0		81.5	47.1	
	20	27.7	2.0		22.5	21.2		7.4	0.4	
	30	5.0	0.0		3.0	1.8		0.5	0.1	
	40	1.9	0.0		0.3	0.1		0.1	0.0	

[a]Populations at the WIEF site were 8-, 16-, 24-, and 32,000 plants per acre.

Table 10. Analysis of variance of percent multiple-eared corn plants for the respective K and population treatments at individual sites in each year

Source of variance	Degrees of freedom	Mean squares 1972	Mean squares 1973
	CWEF		
Blocks	5	0.00311	0.00524
Potassium treatments (K)	2	0.00527++	0.00003
Error (a)	10	0.00183	0.00911
Population-treatments (P)	3	3.18221**	1.42067**
P X K	6	0.00193	0.00038
Error (b)	45	0.00176	0.00699
	WIEF		
Blocks	5	0.00115	0.00128
Potassium treatments (K)	2	0.00113	0.00115
Error (a)	10	0.00246	0.00192

**Denotes 1% level of significance.

++Denotes 10% level of significance.

Table 10. (Continued)

Source of variance	Degrees of freedom	Mean squares 1972	Mean squares 1973
Population-treatments (P)	3	3.45637^{**}	3.75723^{**}
P X K	6	0.00190	0.00131
Error (b)	45	0.00277	0.00270
	SIEF		
Blocks	5	0.00515	
Potassium treatments (K)	2	0.00128	
Error (a)	10	0.00260	
Population-treatments (P)	3	2.88907^{**}	
P X K	6	0.00059	
Error (b)	45	0.00419	
	AF		
Blocks	5		0.00891
Potassium treatments (K)	3		0.00722
Error (a)	15		0.00580

Table 10. (Continued)

Source of variance	Degrees of freedom	Mean squares 1972	1973
Population-treatments (P)	3		1.86717**
P X K	9		0.00644
Error (b)	60		0.00617

percentage decreased significantly when stands were increased to 40,000 plants per acre. The variation in the percentage of multiple-eared plants among population levels, locations, and between years is indicative of the ability of these plants to respond to environmental conditions. The lower plant populations were inadequate for top yields, however, indicating that the individual plants at these populations may have reached a genetic limit in grain production. The average yield per plant cannot continue to increase with decreasing population below the point at which population pressure is no longer the yield-limiting factor.

The percentage of barren plants for each site-year of data are given in Table 11. At the CWEF and WIEF sites barrenness was controlled entirely by plant population as shown by the analysis of variance in Table 12. Potassium fertilizer treatments and plant population levels significantly affected barrenness at the SIEF site in 1972 and the AF site in 1973. Barrenness was controlled by plant population at the AF site in 1974. At the two lower planting rates barrenness was not a significant problem. For the prolific type hybrids grown in 1972 and 1973, the number of barren plants ranged from 3 to 35% at the highest plant population. These data suggest that the advantage of multiple-eared hybrids is not entirely attributed to the production of second ears but in part to the resistance to barrenness exhibited at higher stand levels.

The percentage of barren plants ranged from 6 to 81 for the single-eared hybrid grown in 1974. The large number of barren plants at the WIEF site is a result of the extremely hot and dry conditions which existed during the silking and pollination stages of development.

Table 11. Percent barren corn plants for the respective K and population treatments at individual sites in each year

K rate lb/A	Population 1000 plants/A[a]	CWEF 1972	CWEF 1973	CWEF 1974	WIEF 1972	WIEF 1973	WIEF 1974	SIEF 1972	AF 1973	AF 1974
0	10	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0
	20	0.0	0.0	0.0	0.0	0.3	6.7	3.9	3.3	0.3
	30	2.1	3.6	0.7	1.7	2.8	37.3	9.7	13.3	2.2
	40	7.5	6.7	13.3	4.4	6.1	75.7	20.8	34.9	10.8
50	10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	20	0.2	0.0	0.8	0.0	0.3	9.3	1.1	2.6	0.2
	30	3.6	1.9	1.2	1.5	3.6	33.5	3.6	14.1	3.3
	40	7.7	8.0	15.0	3.1	4.7	76.8	8.8	24.4	10.8
100	10								0.0	0.0
	20								2.6	1.0
	30								9.8	2.5
	40								23.4	5.7
200	10	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0
	20	0.9	0.0	0.0	0.0	0.3	7.2	0.0	1.4	0.0
	30	3.9	3.1	3.3	1.1	2.6	30.0	2.4	13.8	2.5
	40	9.3	7.1	13.2	3.8	4.5	80.8	6.2	19.1	7.7

[a]Populations at the WIEF site were 8-, 16-, 24-, and 32,000 plants per acre.

Table 12. Analysis of variance of percent barren corn plants for the respective K and population treatments at individual sites in each year

Source of variation	Degrees of freedom	Mean squares 1972	1973	1974
		CMEF		
Blocks	5	0.00085	0.00083++	0.0082
Potassium treatments (K)	2	0.00072	0.00000	0.00030
Error (a)	10	0.00046	0.00027	0.00089
Population-treatments (P)	3	0.02552**	0.02126**	0.03859**
P X K	6	0.00016	0.00024	0.00041
Error (b)	45	0.00061	0.00056	0.00081
		WMEF		
Blocks	5	0.00042++	0.00073	0.02916++
Potassium treatments (K)	2	0.00010	0.00012	0.00024
Error (a)	10	0.00014	0.00034	0.00995

**Denotes 1% level of significance.

++Denotes 10% level of significance.

Table 12. (Continued)

Source of variation	Degrees of freedom	Mean squares 1972	1973	1974
Population-treatments (P)	3	0.00570**	0.01046**	1.46383**
P X K	6	0.00008	0.00016	0.00379
Error (b)	45	0.00025	0.00048	0.00894
	SIEF			
Blocks	5	0.00074		
Potassium treatments (K)	2	0.02914^{++}		
Error (a)	10	0.00159		
Population-treatments (P)	3	0.04703**		
P X K	6	0.00632**		
Error (b)	45	0.00130		
	AF			
Blocks	5		0.00734*	0.00095
Potassium treatments (K)	3		0.00895*	0.00033
Error (a)	15		0.00190	0.00043

*Denotes 5% level of significance.

Table 12. (Continued)

Source of variation	Degrees of freedom	Mean squares 1972	1973	1974
Population-treatments (P)	3		0.32258**	0.01487**
P X K	9		0.00689++	0.00050
Error (b)	60		0.00340	0.00068

Lodging

The percentage of lodged plants observed at harvest time is shown in Table 13. The root and stalk lodged categories, when considered separately, did not vary consistently with K or population treatments. Therefore, the two categories were combined for determination of treatment effects.

Lodging was most severe at the CWEF site in 1973 but similar trends were observed at all sites with respect to treatment effects. An analysis of variance for each site-year of data is given in Table 14.

Population treatments significantly affected lodging in each site-year. Lodging increased with increasing plant populations, as was expected. It was of little importance at the lower planting rates but ranged from 2 to 70% at the highest population.

Potassium fertilization significantly affected lodging in 5 of the 9 site-years. At the highest plant population lodging averaged 32, 25, 17, and 15% for the 0, 50, 100, and 200 pound per acre K rates, respectively. The low levels of lodging observed at the WIEF site in 1973 and 1974 and at the AF site in 1974 were probably responsible for the nonsignificant K treatment differences at these sites. Although K fertilization did not significantly affect lodging at the 10% probability level at the CWEF site in 1974, K treatments reduced lodging and were significant at the 14% level.

The effect of K fertilization upon lodging at the highest plant population was determined by fitting the following exponential equation

Table 13. Percent root and stalk lodged corn plants for the respective K and population treatments at the individual sites in each year

K rate lb/A	Population 1000 plants/A[a]	CWEF 1972	CWEF 1973	CWEF 1974	WIEF 1972	WIEF 1973	WIEF 1974	SIEF 1972	AF 1973	AF 1974
0	10	0.0	6.2	2.1	1.1	0.0	2.7	5.5	0.4	0.0
	20	4.4	43.5	15.0	0.9	0.8	5.9	18.3	15.4	0.2
	30	9.5	47.6	29.3	6.9	3.5	8.5	24.0	33.5	1.5
	40	26.2	70.5	53.6	26.0	10.1	7.4	43.3	52.2	5.4
50	10	0.4	1.3	0.5	0.0	0.0	3.5	0.4	0.8	0.8
	20	0.9	33.3	9.5	0.9	1.1	5.7	3.7	10.4	0.2
	30	8.5	52.7	19.2	4.6	2.2	5.5	12.1	24.0	1.3
	40	17.4	61.9	51.6	25.0	5.5	2.1	27.4	30.7	5.0
100	10								0.4	0.0
	20								9.0	0.8
	30								22.6	2.8
	40								32.4	3.0
200	10	0.0	3.2	0.0	0.0	0.0	2.3	6.0	1.3	0.4
	20	0.6	22.9	8.4	1.9	1.4	7.4	2.6	7.0	0.4
	30	5.8	34.8	20.0	4.1	3.5	2.6	9.2	24.2	3.7
	40	8.1	36.8	33.3	10.8	5.3	2.0	18.0	16.9	6.8

[a]Populations at the WIEF site were 8-, 16-, 24-, and 32,000 plants per acre.

Table 14. Analysis of variance of percent lodging for the respective K and population treatments at individual sites in each year

Source of variation	Degrees of freedom	Mean squares 1972	1973	1974
		CWEF		
Blocks	5	0.00248	0.11208++	0.01388
Potassium treatments (K)	2	0.02446**	0.19726*	0.05537
Error (a)	10	0.00268	0.03453	0.02388
Population-treatments (P)	3	0.10616**	0.92864**	0.68421**
P X K	6	0.00986**	0.03485++	0.01576
Error (b)	45	0.00143	0.01728	0.01624
		WIEF		
Blocks	5	0.00990++	0.00181++	0.00543
Potassium treatments (K)	2	0.01315++	0.00126	0.00433
Error (a)	10	0.00336	0.00059	0.00237

**Denotes 1% level of significance.

*Denotes 5% level of significance.

++Denotes 10% level of significance.

Table 14. (Continued)

Source of variation	Degrees of freedom	Mean squares 1972	1973	1974
Population-treatments (P)	3	0.15931^{**}	0.01688^{**}	0.00463^{++}
P X K	6	0.01053^{*}	0.00117	0.00244
Error (b)	45	0.00409	0.00078	0.00244
		SHEF		
Blocks	5	0.00363		
Potassium treatments (K)	2	0.13406^{**}		
Error (a)	10	0.00897		
Population-treatments (P)	3	0.22651^{**}		
P X K	6	0.01748		
Error (b)	45	0.01003		
		AF		
Blocks	5		0.02289	0.00042
Potassium treatments (K)	3		0.07355^{*}	0.00069
Error (a)	15		0.01882	0.00060

Table 14. (Continued)

Source of variation	Degrees of freedom	Mean squares 1972	1973	1974
Population-treatments (P)	3		0.51704**	0.01191**
P X K	9		0.02545*	0.00056
Error (b)	60		0.00967	0.00063

to the data from each site-year in which K fertilization significantly affected lodging.

$$L = c\ 10^{bK}$$

L, c, b, and K have the meaning already indicated in the statistical procedures section. The partial regression coefficient, the significance level, and the R^2 value for each experiment are given in Table 15.

Table 15. Regression coefficients, their significance level, and the R^2-value from fitting a regression equation to percent lodged plants at the highest plant population

Variable	CWEF 1972	CWEF 1973	WIEF 1972	WIEF 1974	SIEF 1972	AF 1973
K	.266	.716	.239	.051	.393	.474
b	-.809**	-.421**	-.503*	-.771**	-.603**	-.639**
R^2	.639	.439	.217	.351	.381	.378

**Denotes 1% level of significance.

Figure 14 shows the effect of K fertilizer treatments on corn lodging at the CWEF, WIEF, and SIEF sites in 1972. This graph shows the predicted lodging percentages as a function of K additions. The horizontal nature of the exponential curves at higher fertilizer rates indicates little response to K fertilization. By substituting coded K fertilizer rates corresponding to 0 pounds per acre and the rate required for maximum yield (Table 6) into the exponential equations for lodging, it

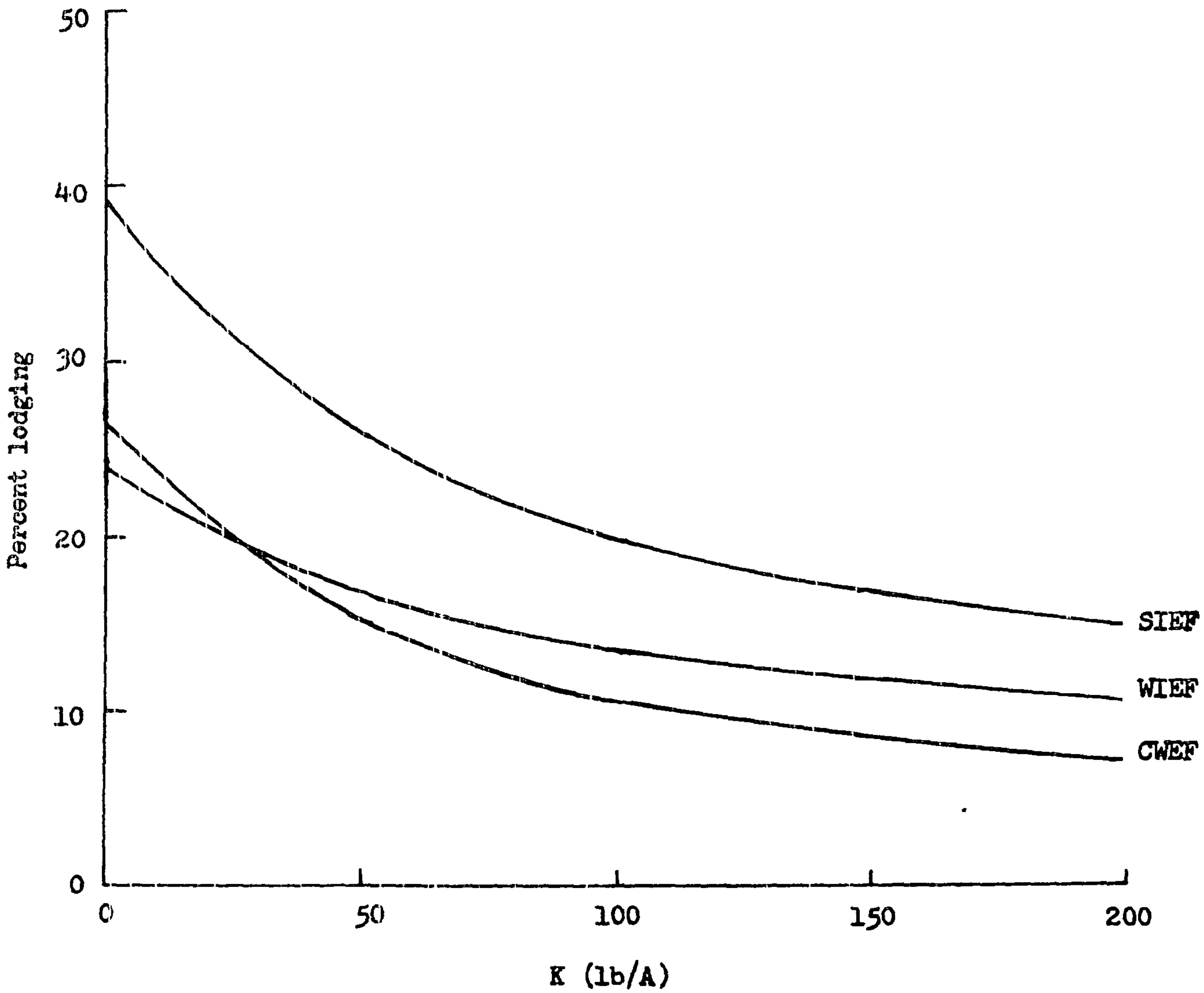

Figure 14. Percent lodging at the highest plant population as influenced by K fertilization at the CWEF, WIEF, and SIEF sites in 1972

is possible to determine the percent reduction in lodging due to K additions. Within the range of yield response to K, lodging was reduced 73, 55, and 56% for the CWEF, WIEF, and SIEF sites, respectively. Potassium rates beyond the rate which would give maximum yield probably would have little effect on lodging.

Quantitative measurements of stalk quality characteristics were made in 1974 at the AF site. Relationships were sought between stalk quality traits known to be related to stalk strength and K fertilization and plant population. The stalk characters with their mean value are given in Table 16. Analysis of variance of the data (Table 17) indicates that plant population significantly affected internode diameter, pith condition, and breaking strength. The effect of K on each of the stalk quality traits was not significant, however. The correlation coefficients (Table 18) reflect the direction by which the stalk quality traits change as plant population levels are increased. There was a decrease in stalk diameter, increase in dead parenchyma in the pith tissue, decrease in breaking strength, and an increase in stalk lodging as plant density increased.

Leaf Analysis

The mean concentrations of N, P, K, Ca, and Mg in corn leaves for each site-year of data are given in Tables 19 and 20. An analysis of variance was calculated to determine treatment effects (Tables 21, 22, 23, 24, and 25).

Table 16. Mean internode diameter, internode length, pith condition, and breaking strength of the second internode of stalk for the respective K and plant population treatments at the AF site in 1974

K rate lb/A	Population 1000 plants/A	Internode Length, cm	Internode Diameter, cm	Pith Condition[a]	Breaking Strength, lb
0	10	7.90	2.58	1.66	103.4
	20	7.62	2.22	2.72	65.0
	30	8.18	2.02	2.78	51.2
	40	8.06	2.06	3.58	42.0
50	10	8.14	2.48	1.90	100.6
	20	7.44	2.28	3.16	58.4
	30	8.30	2.14	3.42	44.6
	40	7.44	1.94	3.26	38.2
100	10	8.06	2.66	1.32	111.0
	20	8.76	2.34	2.92	72.8
	30	8.42	2.20	3.44	44.0
	40	8.32	2.04	3.32	40.6
200	10	8.50	2.60	1.70	102.6
	20	7.80	2.40	2.68	71.4
	30	7.72	2.24	3.16	47.0
	40	8.08	2.06	2.78	44.0

[a]Based on a scale of 1 to 4 representing from 0 to 100% white tissue in the internode.

Table 17. Analysis of variance of internode diameter, internode length, pith condition, and breaking strength of the second internode of stalk at the AF site in 1974

Source of variation	Degrees of freedom	Mean squares			
		Internode Diameter	Internode Length	Pith Condition	Breaking Strength
Blocks	4	.057	1.863	1.226^{++}	397.325^{++}
Potassium treatments (K)	3	.071	1.178	0.445	117.833
Error (a)	12	.028	0.790	0.464	145.250
Population-treatments (P)	3	1.147**	0.317	11.150**	16380.933**
P X K	9	0.016	0.684	0.372	75.744
Error (b)	48	0.012	0.583	0.221	157.802

**Denotes 1% level of significance.

$^{++}$Denotes 10% level of significance.

Table 18. Correlation coefficients between stalk lodging, plant population, and various stalk quality characteristics

	Internode Diameter, cm	Pith Condition	Breaking Strength, lb	Coded Population
Stalk Lodging	-.29**	.21+	-.27*	.37**
Internode Diameter		-.44**	.78**	-.37**
Pith Condition			-.75**	.66**
Breaking Strength				-.85**

**Significant at the 1% level.

++Significant at the 10% level.

<u>Nitrogen</u>

Plant population significantly affected the percent leaf N in each site-year. The level of leaf N decreased as population levels increased. This was probably caused by a decrease in supply of N that each plant was forced to share with its competing neighbors. Population treatment means averaged over all K rates and all site-years indicated a consistent decrease in N level from 3.09% for the lowest plant population treatment to a minimum of 2.77% for the highest stand level. The N content of the leaves at the highest stand level approached the lower limit of sufficiency range generally accepted by research workers.

Potassium fertilizer treatments significantly affected the percent leaf N in 8 of 9 site-years of data. Potassium treatments did not affect the %N at the AF site in 1974. Leaf N decreased with increasing K

Table 19. Mean concentration of N, P, and K in corn leaves for the respective K and plant population treatments at individual sites in each year

K rate lb/A	Population 1000 plants/A	%N 1972	%N 1973	%N 1974	%P 1972	%P 1973	%P 1974	%K 1972	%K 1973	%K 1974
					CWEF					
0	10	3.21	3.03	2.94	.388	.363	.319	1.29	1.46	1.12
	20	3.19	2.89	2.79	.376	.340	.279	1.30	1.49	1.11
	30	3.15	2.77	2.69	.393	.344	.304	1.28	1.46	1.04
	40	3.07	2.80	2.67	.392	.336	.297	1.16	1.37	1.01
50	10	3.28	3.02	2.94	.380	.341	.289	1.50	1.94	1.70
	20	3.14	2.83	2.72	.382	.345	.296	1.48	1.93	1.59
	30	3.07	2.78	2.67	.374	.321	.269	1.34	1.84	1.42
	40	3.06	2.73	2.60	.380	.318	.276	1.33	1.71	1.31
200	10	3.19	3.00	2.89	.371	.325	.272	1.69	2.37	2.11
	20	3.08	2.77	2.61	.378	.316	.252	1.67	2.35	2.07
	30	3.05	2.73	2.70	.367	.316	.267	1.67	2.37	2.03
	40	2.96	2.64	2.56	.366	.298	.254	1.60	2.30	1.97
					WIEF					
0	8	3.17	3.27	3.10	.322	.315	.313	1.58	1.37	1.56
	16	3.12	3.13	2.80	.309	.304	.303	1.52	1.37	1.45
	24	2.98	3.02	2.72	.308	.300	.300	1.55	1.47	1.46
	32	2.91	2.91	2.60	.311	.293	.291	1.47	1.41	1.35

Table 19. (Continued)

K rate lb/A	Population 1000 plants/A	%N 1972	%N 1973	%N 1974	%P 1972	%P 1973	%P 1974	%K 1972	%K 1973	%K 1974
50	8	3.18	3.29	3.00	.305	.318	.323	1.62	1.58	1.84
	16	3.13	3.11	2.76	.308	.298	.305	1.62	1.47	1.70
	24	3.04	3.12	2.66	.307	.304	.306	1.72	1.54	1.66
	32	2.89	2.99	2.62	.297	.291	.303	1.63	1.56	1.62
200	8	3.21	3.30	3.03	.313	.318	.312	2.02	2.02	2.34
	16	3.12	3.26	2.83	.315	.314	.303	2.07	2.08	2.36
	24	3.04	3.09	2.75	.311	.302	.291	1.99	2.04	2.37
	32	3.01	2.99	2.67	.305	.298	.291	1.98	2.06	2.30
				SIEF						
0	10	3.06			.406			0.75		
	20	2.99			.411			0.72		
	30	2.73			.395			0.76		
	40	2.84			.392			0.71		
50	10	3.12			.340			1.03		
	20	3.02			.346			1.08		
	30	2.99			.341			1.22		
	40	2.89			.346			1.19		
200	10	3.19			.309			1.63		
	20	3.09			.311			1.72		
	30	2.94			.308			1.77		
	40	2.84			.292			1.82		

Table 19. (Continued)

K rate lb/A	Population 1000 plants/A	%N 1972	%N 1973	%N 1974	%P 1972	%P 1973	%P 1974	%K 1972	%K 1973	%K 1974
				AF						
0	10		3.18	2.96		.347	.294		1.25	1.25
	20		3.04	2.66		.350	.282		1.27	1.16
	30		3.00	2.45		.349	.252		1.24	1.06
	40		2.95	2.47		.341	.249		1.15	1.01
50	10		3.10	2.80		.337	.285		1.72	1.53
	20		2.98	2.54		.334	.259		1.63	1.44
	30		2.86	2.39		.342	.236		1.58	1.47
	40		2.83	2.29		.335	.228		1.50	1.33
100	10		3.13	2.81		.336	.281		1.92	1.76
	20		2.91	2.61		.322	.262		1.78	1.64
	30		2.81	2.61		.327	.236		1.74	1.55
	40		2.81	2.33		.333	.232		1.70	1.51
200	10		3.08	2.85		.331	.281		2.13	1.87
	20		2.93	2.55		.322	.258		2.07	1.76
	30		2.78	2.45		.327	.243		1.97	1.72
	40		2.73	2.33		.316	.226		1.98	1.69

Table 20. Mean concentration of Ca and Mg in corn leaves for the respective K and plant population treatments at individual sites in each year

K rate lb/A	Population 1000 plants/A	%Ca 1972	%Ca 1973	%Ca 1974	%Mg 1972	%Mg 1973	%Mg 1974
			CWEF				
0	10	.560	.678	.644	.475	.563	.689
	20	.494	.653	.606	.459	.643	.747
	30	.488	.617	.610	.481	.610	.819
	40	.516	.573	.617	.540	.676	.881
50	10	.479	.621	.535	.337	.521	.404
	20	.437	.586	.535	.373	.602	.540
	30	.449	.558	.563	.426	.570	.634
	40	.446	.547	.560	.442	.599	.696
200	10	.389	.519	.454	.265	.321	.292
	20	.384	.485	.467	.286	.345	.393
	30	.379	.467	.459	.292	.377	.411
	40	.374	.440	.465	.316	.394	.436
			WIEF				
0	8	.588	.529	.632	.465	.532	.606
	16	.522	.478	.683	.471	.537	.782
	24	.515	.477	.617	.481	.571	.755
	32	.523	.492	.599	.554	.661	.802
50	8	.581	.459	.584	.477	.359	.534
	16	.529	.411	.626	.524	.401	.719
	24	.478	.405	.591	.458	.438	.700
	32	.467	.421	.598	.482	.498	.738
200	8	.497	.389	.497	.332	.256	.297
	16	.470	.379	.525	.366	.284	.420
	24	.451	.370	.524	.379	.301	.457
	32	.432	.352	.527	.381	.315	.515
			SIEF				
0	10	.674			.954		
	20	.568			.945		
	30	.562			.925		
	40	.526			.918		

Table 20. (Continued)

K rate lb/A	Population 1000 plants/A	%Ca 1972	%Ca 1973	%Ca 1974	%Mg 1972	%Mg 1973	%Mg 1974
50	10	.616			.675		
	20	.530			.679		
	30	.490			.615		
	40	.474			.628		
200	10	.462			.364		
	20	.415			.361		
	30	.398			.355		
	40	.375			.351		
			AF				
0	10		.623	.632		.594	.506
	20		.551	.581		.650	.536
	30		.557	.636		.711	.629
	40		.561	.636		.739	.652
50	10		.502	.605		.402	.393
	20		.490	.557		.527	.456
	30		.484	.569		.583	.477
	40		.481	.612		.612	.544
100	10		.469	.525		.325	.335
	20		.468	.545		.460	.415
	30		.457	.554		.508	.451
	40		.441	.560		.501	.467
200	10		.433	.488		.270	.287
	20		.423	.509		.352	.377
	30		.426	.509		.428	.396
	40		.422	.533		.431	.417

Table 21. Analysis of variance of percent leaf N for each site-year of data

Source of variation	Degrees of freedom	Mean squares 1972	1973	1974
		CWEF		
Blocks	5	0.02465**	0.00477	0.03252*
K treatments (K)	2	0.05025**	0.05093*	0.04303*
Error (a)	10	0.00285	0.01191	0.00900
Population treatments (P)	3	0.12537**	0.31216**	0.32654**
P x K	6	0.00739	0.00638	0.01194*
Error (b)	45	0.00729	0.01003	0.00494
		WIEF		
Blocks	5	0.00912	0.01056	0.01194
K treatments (K)	2	0.08943*	0.03709*	0.02150++
Error (a)	10	0.01892	0.00597	0.00762
Population treatments (P)	3	0.29442**	0.34026**	0.57409**
P x K	6	0.02202	0.01083++	0.00669
Error (b)	45	0.01303	0.00524	0.00410
		SIEF		
Blocks	5	0.00912		
K treatments (K)	2	0.08943*		
Error (a)	10	0.01892		

**Denotes 1% level of significance.

*Denotes 5% level of significance.

++Denotes 10% level of significance.

Table 21. (Continued)

Source of variation	Degrees of freedom	Mean squares 1972	1973	1974
Population treatments (P)	3	0.29442**		
P x K	6	0.02202		
Error (b)	45	0.01303		
	AF			
Blocks	5		0.01373	0.10540++
K treatments (K)	3		0.11685**	0.06872
Error (a)	15		0.01149	0.04247
Population treatments (P)	3		0.41717**	1.17990**
P x K	9		0.00613	0.00703
Error (b)	60		0.00695	0.01413

Table 22. Analysis of variance of percent leaf P for each site-year of data

Source of variation	Degrees of freedom	Mean squares 1972	1973	1974
		CWEF		
Blocks	5	0.00137	0.00579*	0.00120
K treatments (K)	2	0.00168	0.00630*	0.00894**
Error (a)	10	0.00105	0.00106	0.00066
Population treatments (P)	3	0.00001	0.00212**	0.00125*
P x K	6	0.00031	0.00033	0.00094*
Error (b)	45	0.00040	0.00019	0.00035
		WIEF		
Blocks	5	0.00053	0.00007	0.00115*
K treatments (K)	2	0.00047	0.00019	0.00067
Error (a)	10	0.00026	0.00013	0.00024
Population treatments (P)	3	0.00026**	0.00163**	0.00153**
P x K	6	0.00013	0.00010++	0.00007
Error (b)	45	0.00006	0.00005	0.00013
		SIEF		
Blocks	5	0.00035		
K treatments (K)	2	0.05593**		
Error (a)	10	0.00054		

**Denotes 1% level of significance.

*Denotes 5% level of significance.

++Denotes 10% level of significance.

Table 22. (Continued)

Source of variation	Degrees of freedom	Mean squares 1972	1973	1974
Population treatments (P)	3	0.00047		
P x K	6	0.00025		
Error (b)	45	0.00027		
	AF			
Blocks	5		0.00044	0.00159**
K treatments (K)	3		0.00229	0.00173**
Error (a)	15		0.00124	0.00035
Population treatments (P)	3		0.00024	0.01309**
P x K	9		0.00015	0.00008
Error (b)	60		0.00015	0.00009

Table 23. Analysis of variance of percent leaf K for each site-year of data

Source of variation	Degrees of freedom	Mean square 1972	1973	1974
		CWEF		
Blocks	5	0.01683	0.02230	0.06173*
K treatments (K)	2	0.98333**	4.89441**	5.75073**
Error (a)	10	0.03747	0.04524	0.01527
Population treatments (P)	3	0.06608*	0.07005**	0.15920**
P x K	6	0.01011	0.01196	0.03017*
Error (b)	45	0.00781	0.01215	0.01407
		WIEF		
Blocks	5	0.21120	0.16658	0.31645++
K treatments (K)	2	1.53087**	2.77719**	5.01983**
Error (a)	10	0.13074	0.09365	0.10516
Population treatments (P)	3	0.01068	0.00583	0.07290**
P x K	6	0.01249	0.01205	0.01520
Error (b)	45	0.01108	0.01214	0.01268
		SIEF		
Blocks	5	0.00881		
K treatments (K)	2	6.11010**		
Error (a)	10	0.01098		

**Denotes 1% level of significance.

*Denotes 5% level of significance.

++Denotes 10% level of significance.

Table 23. (Continued)

Source of variation	Degrees of freedom	Mean squares 1972	1973	1974
Population treatments (P)	3	0.05068**		
P x K	6	0.02006*		
Error (b)	45	0.00735		
	AF			
Blocks	5		0.08692	0.05134
K treatments (K)	3		2.80028**	1.78871**
Error (a)	15		0.04336	0.07819
Population treatments (P)	3		0.13257**	0.19169**
P x K	9		0.00896	0.00597
Error (b)	60		0.01065	0.01511

Table 24. Analysis of variance of percent leaf Ca for each site-year of data

Source of variation	Degrees of freedom	Mean squares 1972	Mean squares 1973	Mean squares 1974
		CWEF		
Blocks	5	0.00105	0.05482**	0.00132
K treatments (K)	2	0.10673**	0.14414**	0.15046**
Error (a)	10	0.00187	0.00367	0.00076
Population treatments (P)	3	0.00573**	0.02432**	0.00045
P x K	6	0.00143*	0.00059	0.00145
Error (b)	45	0.00059	0.00159	0.00103
		WIEF		
Blocks	5	0.01055**	0.00173	0.00906
K treatments (K)	2	0.03478**	0.08915**	0.08291**
Error (a)	10	0.00084	0.00273	0.00347
Population treatments (P)	3	0.02444**	0.00672**	0.00622**
P x K	6	0.00183**	0.00089	0.00243
Error (b)	45	0.00036	0.00068	0.00126
		SIEF		
Blocks	5	0.00261		
K treatments (K)	2	0.18041**		
Error (a)	10	0.00204		

**Denotes 1% level of significance.

*Denotes 5% level of significance.

++Denotes 10% level of significance.

Table 24. (Continued)

Source of variation	Degrees of freedom	Mean squares 1972	1973	1974
Population treatments (P)	3	0.05362**		
P x K	6	0.00179		
Error (b)	45	0.00127		
	AF			
Block	5		0.00414	0.00463
K treatments	3		0.09505**	0.05602**
Error (a)	15		0.00231	0.00455
Population treatments (P)	3		0.00449**	0.00563*
P x K	9		0.00133	0.00215
Error (b)	60		0.00104	0.00206

Table 25. Analysis of variance of percent leaf Mg for each site-year of data

Source of variation	Degrees of freedom	Mean squares 1972	1973	1974
		CWEF		
Blocks	5	0.00269	0.06397	0.00854
K treatments (K)	2	0.23885**	0.47122**	0.96780**
Error (a)	10	0.00672	0.02751	0.00879
Population treatments (P)	3	0.01904**	0.02448**	0.14607**
P x K	6	0.00258	0.00218	0.00824**
Error (b)	45	0.00192	0.00327	0.00255
		WIEF		
Blocks	5	0.04084++	0.00504	0.07459
K treatments (K)	2	0.12434**	0.49275**	0.66151**
Error (a)	10	0.01319	0.00844	0.03694
Population treatments (P)	3	0.00737**	0.03957**	0.14625**
P x K	6	0.00530**	0.00324	0.00228
Error (b)	45	0.00145	0.00200	0.00309
		SIEF		
Blocks	5	0.00208		
K treatments (K)	2	2.00341**		
Error (a)	10	0.00404		

**Denotes 1% level of significance.

*Denotes 5% level of significance.

++Denotes 10% level of significance.

Table 25. (Continued)

Source of variation	Degrees of freedom	Mean square 1972	1973	1974
Population treatments (P)	3	0.00572		
P x K	6	0.00118		
Error (b)	45	0.00291		
	AF			
Blocks	5		0.01492*	0.01668
K treatments (K)	3		0.40300**	0.19731**
Error (a)	15		0.00378	0.01042
Population treatments (P)	3		0.14888**	0.08761**
P x K	9		0.00202	0.00203
Error (b)	60		0.00214	0.00165

fertilizer rates at the CWEF and AF sites. The decrease was probably a result of increased growth and higher yields, causing dilution of elements. Percent leaf N, averaged over all population treatments and all site-years where K treatments significantly reduced leaf N, decreased from 2.96% for the 0 K treatments to 2.79% for the 200 pound per acre K treatment.

The data from the WIEF and SIEF sites indicates a small, relatively consistent increase in %N with increasing K rates. The magnitude of the increase was on the order of .06% N.

Replication differences were not consistent over years making it difficult to attribute these to variations in initial soil fertility. The significant replication differences at the AF site in 1974 resulted from heavy spring rains which caused N losses on 2 of the 6 replicates. These replicates had significantly lower leaf N percentages than the replicates not showing N deficiencies.

Significant K rate by plant population interactions occurred in 1974 at the CWEF site and in 1973 at the WIEF site. At the CWEF site leaf N decreased with increasing K fertilizer rates at the 10-, 20-, and 40,000 plant per acre populations and increased with increasing K rates at the 30,000 plant per acre population. At the WIEF in 1973 the magnitude of the increase in leaf N with increasing K fertilizer rates was greater at the 16,000 plant per acre than at the 8-, 24-, and 32,000 plant per acre populations.

The N levels at all sites in 1974 were substantially below the 1972 and 1973 levels. Soil moisture conditions prior to sampling were unfavorable for nutrient absorption and high leaf contents.

Phosphorus

The percent leaf P was significantly affected by plant population in 6 of the 9 site-years of data. Population treatment means averaged over all K treatments and site-years indicated a small, consistent decrease in leaf P from .311% at the lowest plant per acre population to a minimum of .287% at the highest stand level. The P levels at each treatment combination appeared to be adequate with the 1974 values significantly lower than the 1972 and 1973 values.

Potassium fertilizer treatments significantly decreased the percent leaf P in 4 of the 9 site-years of data. The associated yield responses with increasing rates of applied K probably caused a dilution of plant nutrients.

The significance of replication and K rate by plant population terms was not consistent at any location.

Potassium

Leaf K contents varied greatly among years and reflected the soil test level of K at individual sites. Plant population level significantly affected the percent leaf K in 7 of the 9 site-years. Leaf K percentages decreased from 1.64 at the lowest plant population to 1.51 at the highest stand level.

Significant increases in leaf K occurred with increasing rates of K fertilization. Percent leaf K, averaged over all population treatments and all site-years, increased from 1.25% for the check plots to 2.00% for the 200 pound per acre K treatment. The maximum range in leaf K content (0.71% to 1.82%) occurred at the SIEF site in 1972. The relatively high yield levels associated with low leaf K values from the check plots and those which received 50 pounds of K per acre probably reflects the favorable weather conditions which existed in 1972 at the SIEF site.

Calcium

Calcium uptake was significantly reduced by both increasing plant populations and by increasing K fertilizer rates. Population treatment means averaged over all K fertilizer rates decreased from 0.537% Ca at the lowest stand levels to 0.482% Ca at the highest stand levels.

Competition between K and Ca would be expected to reduce Ca uptake by the plants. The level of leaf Ca decreased from 0.578% for the check plots to 0.447% for the plots receiving 200 pounds of K per acre annually.

The Ca levels appeared to be adequate in each site-year of data.

Magnesium

Leaf Mg percentages were significantly affected by plant population treatments. As percent leaf K and Ca decreased with increasing plant populations, the percent leaf Mg increased. Thereby a relatively constant level of cations was maintained within the plants receiving identical K treatments. The milliequivalents of K, Ca, and Mg for each site-year are given in Table 26.

Table 26. Mean milliequivalents of K, Ca, and Mg in corn leaves for the respective K and plant population treatments at individual sites in each year

K rate lb/A	Population 1000 plants/A	Meq/100 g 1972 K	1972 Ca	1972 Mg	1972 Total	1973 K	1973 Ca	1973 Mg	1973 Total	1974 K	1974 Ca	1974 Mg	1974 Total
						CWEF							
0	10	33.1	28.0	39.6	100.7	37.4	33.9	46.9	118.2	28.6	32.2	57.4	118.2
	20	33.3	24.7	38.2	96.2	38.3	32.6	53.6	124.5	28.4	30.3	62.2	120.9
	30	32.8	24.4	40.1	97.3	37.4	30.9	50.8	119.1	26.7	30.5	68.3	125.5
	40	29.7	25.8	45.0	100.5	35.0	28.7	56.3	120.0	25.9	30.9	73.4	130.2
50	10	38.5	24.0	28.1	90.6	49.8	31.0	43.4	124.2	43.6	26.7	33.7	104.0
	20	38.1	21.9	31.1	91.1	49.6	29.3	50.1	129.0	40.8	26.8	45.0	112.6
	30	34.4	22.4	35.5	92.3	47.2	27.9	47.5	122.6	36.3	28.2	52.8	117.3
	40	34.0	22.3	36.9	93.2	43.8	27.3	49.9	121.0	33.5	28.0	58.0	119.5
200	10	43.4	19.4	22.1	84.9	60.7	25.9	26.8	113.4	54.1	22.7	24.3	101.1
	20	42.8	19.2	23.8	85.8	60.3	24.2	28.7	113.2	53.0	23.3	32.7	109.0
	30	42.7	19.0	24.3	86.0	60.7	23.4	31.4	115.5	52.1	22.9	34.3	109.3
	40	41.1	18.7	26.3	86.1	59.0	22.0	32.8	113.8	50.6	23.3	36.3	110.2
						WIEF							
0	8	40.6	29.4	38.8	108.8	35.3	26.4	44.3	106.0	39.9	31.6	50.5	122.0
	16	39.1	26.1	39.2	104.4	35.2	23.9	44.8	103.9	37.2	34.1	65.2	136.5
	24	39.7	25.7	40.1	105.5	37.8	23.8	47.6	109.2	37.4	30.8	62.9	131.1
	32	37.8	26.1	46.2	110.1	36.1	24.6	55.1	115.8	34.6	29.9	66.9	131.4

Table 26. (Continued)

K rate lb/A	Population 1000 plants/A	Meq/100 g 1972 K	Ca	Mg	Total	1973 K	Ca	Mg	Total	1974 K	Ca	Mg	Total
50	8	41.7	29.0	39.7	110.4	40.6	22.9	29.9	93.4	47.2	29.2	44.5	120.9
	16	41.5	26.4	43.7	111.6	37.8	20.5	33.4	91.7	43.6	31.3	59.9	134.8
	24	44.0	23.9	38.2	106.1	39.5	20.3	36.5	96.3	42.5	29.5	58.4	130.4
	32	41.9	23.3	40.1	105.3	40.0	21.0	41.5	102.5	41.7	29.9	61.5	133.1
200	8	51.7	24.9	27.6	104.2	51.9	19.5	21.3	92.7	60.0	24.8	24.8	109.6
	16	53.2	23.5	30.5	107.2	53.4	19.0	23.7	96.1	60.5	26.2	35.0	121.7
	24	51.1	22.5	31.6	105.2	52.4	18.5	25.0	95.9	60.7	26.2	38.1	125.0
	32	50.9	21.6	31.7	104.2	52.8	17.6	26.3	96.7	59.0	26.4	42.9	128.3
							SIEF						
0	10	19.2	33.7	79.5	132.4								
	20	18.6	28.4	78.7	125.7								
	30	19.4	28.1	77.1	124.6								
	40	18.2	26.3	76.5	121.0								
50	10	26.5	30.8	56.2	113.5								
	20	27.8	26.5	56.6	110.9								
	30	31.4	24.5	51.3	107.2								
	40	30.5	23.7	52.4	106.6								
200	10	41.9	23.1	30.3	95.3								
	20	44.2	20.8	30.1	95.1								
	30	45.3	19.9	29.6	94.8								
	40	46.8	18.7	29.2	94.7								

Table 26. (Continued)

K rate lb/A	Population 1000 plants/A	Meq/100 g 1972 K	Ca	Mg	Total	1973 K	Ca	Mg	Total	1974 K	Ca	Mg	Total
						AF							
0	10					32.0	31.2	49.5	112.7	32.0	31.6	42.1	105.7
	20					32.7	27.5	54.1	114.3	29.7	29.0	44.6	103.3
	30					31.8	27.8	59.3	118.9	27.1	31.8	52.4	111.3
	40					29.5	28.0	61.6	119.1	26.7	31.8	54.3	112.8
50	10					44.0	25.1	33.5	102.6	39.3	30.2	32.8	102.3
	20					41.9	24.5	43.9	110.3	37.0	27.8	38.0	102.8
	30					40.6	24.2	48.6	113.4	37.6	28.4	39.7	105.8
	40					38.4	24.1	51.0	113.5	34.2	30.6	45.3	110.1
100	10					49.4	23.4	27.1	99.9	45.1	26.2	27.9	99.2
	20					45.7	23.4	38.3	107.4	42.1	27.3	34.6	104.0
	30					44.7	22.8	42.4	109.9	39.8	27.7	37.5	105.0
	40					43.6	22.1	41.7	107.4	38.7	28.0	38.9	105.6
200	10					54.7	21.7	22.5	98.9	48.1	24.4	23.9	96.4
	20					53.2	21.1	29.4	103.7	45.1	25.4	31.4	101.9
	30					50.6	21.3	35.7	107.6	44.2	25.4	33.0	102.6
	40					50.9	21.1	35.9	107.9	43.4	26.6	34.7	104.7

Figure 15 illustrates the above relationship for the CWEF site in 1972. At the 200 pound per acre K rate leaf K decreased from 43.4 meq/100 g at the 10,000 plant per acre stand to 41.1 meq/100 g at the 40,000 plant per acre stand, leaf Ca decreased from 19.4 meq/100 g to 18.7 meq/100 g, and leaf Mg increased from 22.1 meq/100 g to 26.3 meq/100 g. The total milliequivalents of K, Ca, and Mg were 84.9, 85.8, 86.0, and 86.1 meq/100 g for the 10-, 20-, 30-, and 40,000 plant populations, respectively.

As K fertilizer rates were increased, a significant reduction in percent leaf Mg occurred. Percent leaf Mg, averaged over all population treatments and all site-years decreased from 0.654% for the check plots to 0.356% for the 200 pound per acre K treatments. These leaf Mg percentages appeared to be adequate for maximum yields.

The total milliequivalents of K, Ca, and Mg decreased significantly with increasing K fertilizer rates. The yield response associated with K applications probably caused a dilution of elements. Figure 16 illustrates the effect of K fertilization on the milliequivalents of K, Ca, and Mg at the AF site in 1974. At the 30,000 plant per acre population the sums of the cations were 111.3, 105.8, 105.0, and 102.6 meq/100 g for the 0, 50, 100, and 200 pound per acre K rates, respectively. The ranges for individual cations were 27.1 meq/100 g to 44.2 meq/100 g, 31.8 meq/100 g to 25.4 meq/100 g, and 52.4 meq/100 g to 33.0 meq/100 g for K, Ca, and Mg, respectively.

The ratio of K to (Ca + Mg) was determined for each site-year of data (Table 27). Potassium fertilization increased the K to (Ca + Mg) ratio while plant population decreased the ratio in most cases.

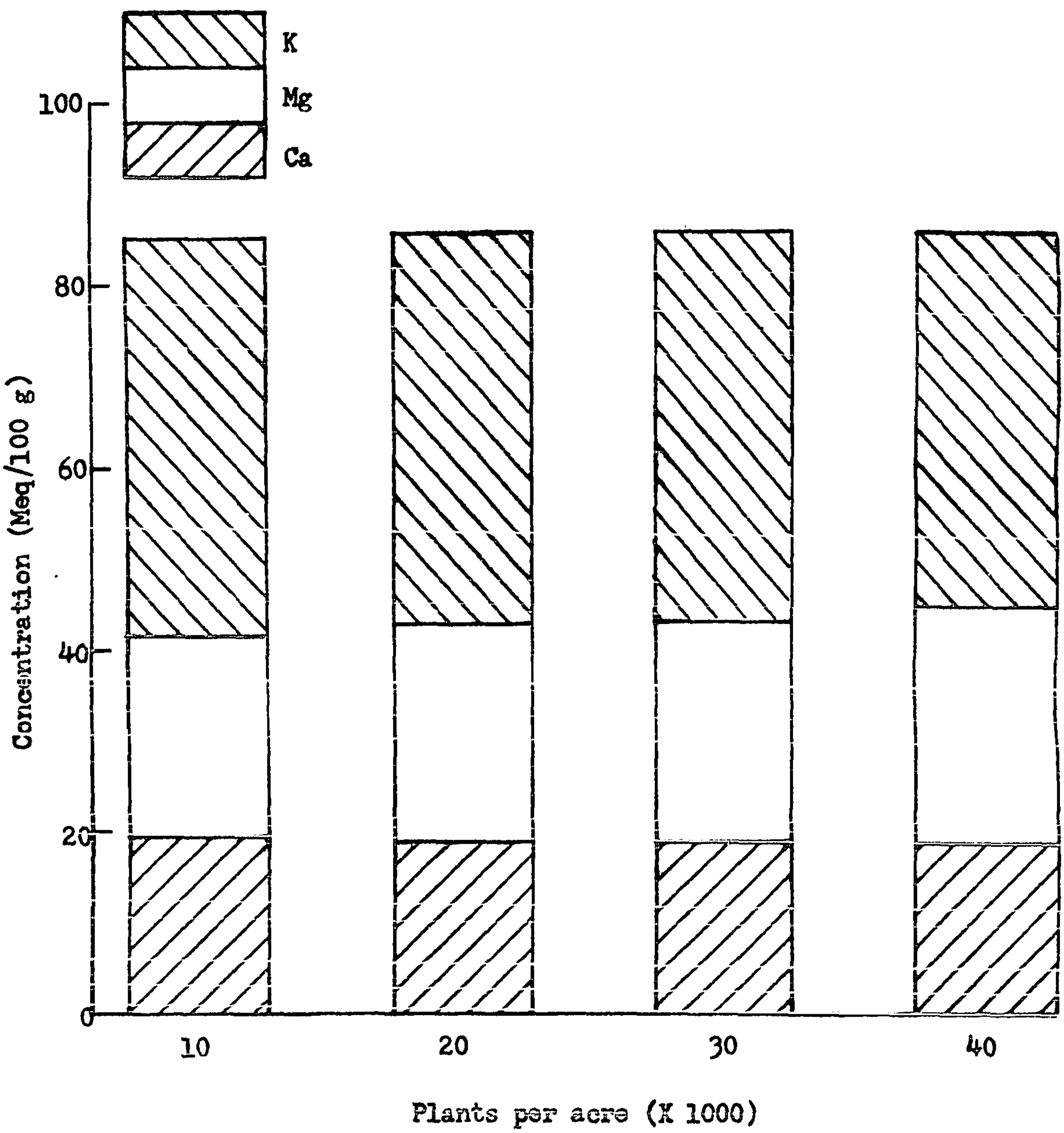

Figure 15. The milliequivalence of K, Ca, and Mg in corn leaves as influenced by plant population for the 200 pound per acre potassium rate at the CWEF site in 1972

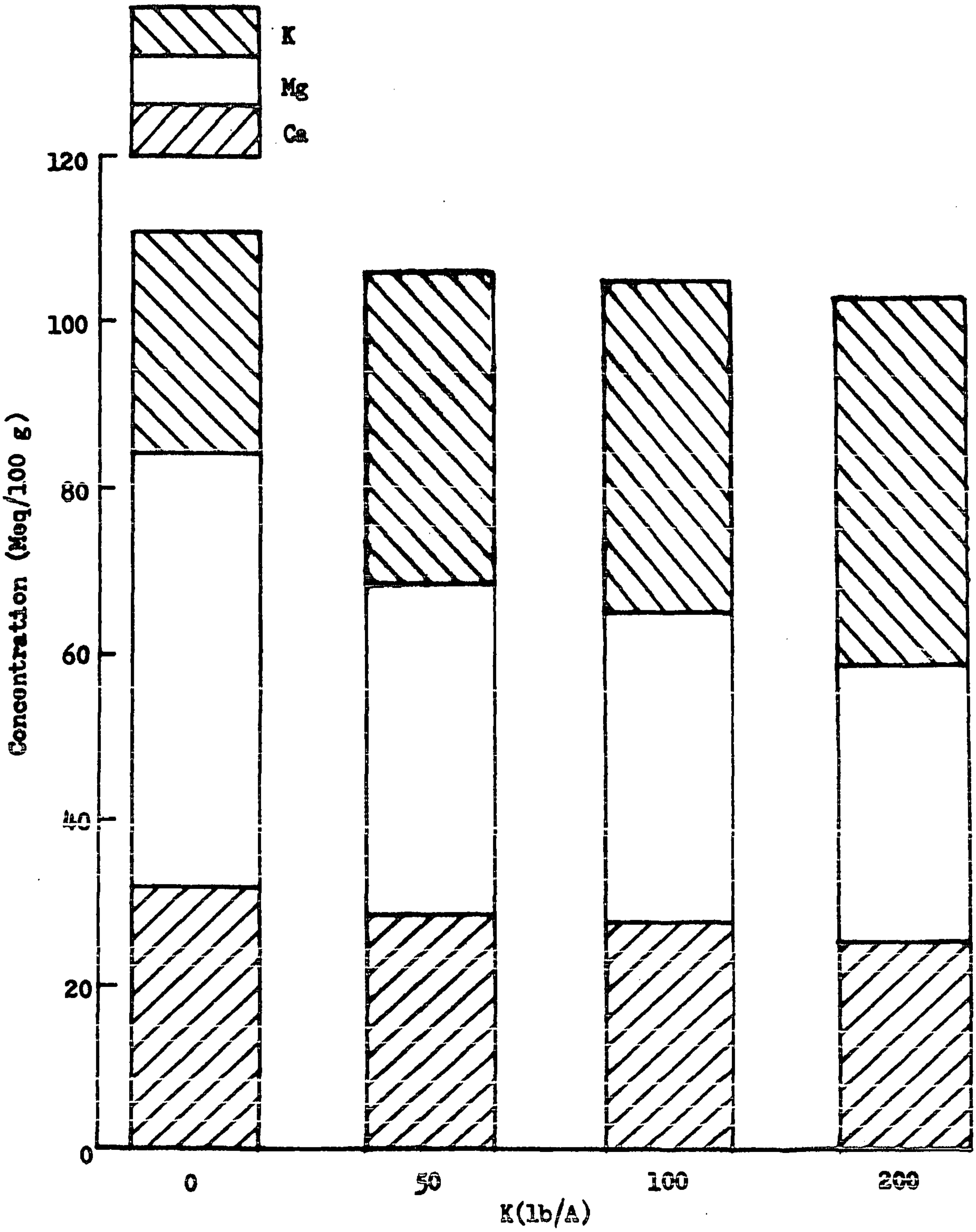

Figure 16. The milliequivalents of K, Ca, and Mg in corn leaves as influenced by K fertilization for the 30,000 plant per acre population level at the AF site in 1974

Table 27. Mean cation milliequivalent ratios in corn leaves for the respective K and plant population treatments at individual sites in each year

K rate lb/A	Population 1000 plants/A	K to (Ca + Mg) meq/meq								
		CWEF			WIEF			SIEF	AF	
		1972	1973	1974	1972	1973	1974	1972	1973	1974
0	10[a]	0.49	0.47	0.32	0.62	0.50	0.51	0.17	0.41	0.46
	20	0.53	0.46	0.32	0.63	0.52	0.40	0.17	0.41	0.41
	30	0.52	0.47	0.28	0.62	0.55	0.41	0.19	0.37	0.33
	40	0.43	0.43	0.25	0.55	0.46	0.37	0.18	0.33	0.31
50	10	0.75	0.68	0.72	0.61	0.77	0.68	0.31	0.75	0.63
	20	0.72	0.64	0.57	0.61	0.71	0.50	0.34	0.61	0.58
	30	0.60	0.63	0.45	0.72	0.70	0.49	0.42	0.56	0.56
	40	0.59	0.57	0.39	0.67	0.65	0.47	0.41	0.52	0.46
100	10								0.98	0.85
	20								0.78	0.69
	30								0.69	0.61
	40								0.69	0.58
200	10	1.05	1.16	1.16	0.99	1.28	1.22	0.79	1.24	1.01
	20	1.01	1.14	0.95	0.99	1.27	1.01	0.89	1.07	0.79
	30	1.00	1.12	0.92	0.95	1.22	0.95	0.92	0.89	0.76
	40	0.91	1.08	0.86	0.96	1.20	0.86	0.98	0.89	0.71

[a]Populations at the WIEF site were 8-, 16-, 24-, and 32,000 plants per acre.

Soil Test

Soil samples were taken from the 0 to 6 inch layer of each whole plot prior to each fertilizer application. Mean soil test values for each K fertilization treatment are shown in Table 28. The levels of exchangeable K in the check plots at each site varied with time. The exchangeable K level of the soil in the check plots varied by as much as 37 pounds per acre in a one-year period. While some of the variation was undoubtedly due to sampling and analytical error, it appears that time of sampling, moisture conditions at the time of sampling, and length of storage of the samples also contributed to the variability in exchangeable K.

Additions of 200 pounds of K per acre annually were found to increase the exchangeable K level in the soil at all locations. The 100 pound per acre K rate increased the level of exchangeable K in the soil at the AF site. The duration of the experiment was not sufficient to determine the effect of the 50 pound per acre K rate on the accumulation or decline of exchangeable K in the soil. However, it appears that this rate may be large enough to cause significant increases in the exchangeable K level at the AF site.

The exchangeable K level of the soil in the check plots at the termination of the experiment was subtracted from the exchangeable K level in the plots receiving 200 pounds of K per acre in order to determine the increase in exchangeable K resulting from fertilizer additions. The total pounds of K applied per acre was then divided by

Table 28. Soil test values for soil samples taken prior to fertilization and taken after annual K additions

Soil Type	K rate lb/A	P (pp2m)	K (pp2m)	pH	P (pp2m)	K (pp2m)	pH	P (pp2m)	K (pp2m)	pH	P (pp2m)	K (pp2m)	pH
						Number of K additions							
			0			1			2			3	
			Spring 1971[a]			Fall 1971			Fall 1972			Fall 1973	
Webster	0	41	124	7.0	76	123	7.0	74	104	6.9	72	83	6.5
Sicl	50	44	127	6.9	75	128	6.7	83	125	6.9	70	99	6.5
	200	43	128	6.9	74	157	7.0	82	223	6.9	67	155	6.6
			4										
			Fall 1974										
	0	81	96	6.3									
	50	73	117	6.2									
	200	76	255	6.3									
			0			1			2				
			Spring 1971			Spring 1972			Fall 1972				
Edina	0	26	70	6.9	38	82	6.9	40	65	6.9			
Sil	50	19	71	6.9	35	98	6.9	43	81	6.9			
	200	23	69	6.9	39	143	6.9	42	136	6.9			

[a]Indicates time of sampling.

Table 28. (Continued)

Soil Type	K rate lb/A	P (pp2m)	K (pp2m)	pH	P (pp2m)	K (pp2m)	pH	P (pp2m)	K (pp2m)	pH	P (pp2m)	K (pp2m)	pH
			0			1			2			3	
			Spring 1972			Fall 1972			Spring 1974			Fall 1974	
Ida	0	6	123	7.5	6	112	7.5	9	115	7.9	12	130	8.1
Sil	50	14	99	7.5	14	96	7.5	23	99	8.0	21	123	8.1
	200	7	105	7.4	7	124	7.5	20	195	8.0	18	261	8.1
			0			1			2			3	
			Spring 1972			Fall 1972			Spring 1974			Fall 1974	
Monona	0	44	112	7.2	44	99	7.2	70	97	7.2	65	97	7.0
Sil	50	42	117	7.3	42	103	7.2	56	113	7.2	54	131	7.3
	200	42	122	7.3	41	155	7.2	64	189	7.2	51	229	7.1
			0			1			2				
			Spring 1973			Fall 1973			Fall 1974				
Webster	0	17	127	6.5	45	90	6.0	48	117	5.9			
Sicl	50	16	131	6.5	56	105	6.0	53	147	6.1			
	100	19	115	6.4	49	115	5.9	53	172	6.0			
	200	14	119	6.5	52	114	6.0	44	201	6.1			

the increase in exchangeable K per acre to determine the pounds of fertilizer K required to increase the exchangeable K level 1 pound per acre. Potassium additions of 5.0, 5.6, 4.5, and 4.8 pounds were required to increase the exchangeable K level 1 pound for the CWEF, SIEF, WIEF, and AF sites, respectively. These results are in agreement with those of Hanway et al. (1962).

Economics of Potassium Fertilization

The 1972 and 1973 yield data from the WIEF site were combined to determine the effects of changing K and corn prices on the economic optimum K rate per acre. Data from other locations represented different hybrids each year and were not selected. A multiple regression equation relating yield to plant population and K fertilization was fitted to the data. The stand level required for maximum yield was substituted into the equation and a yield response curve to K fertilization was obtained. The equation was as follows:

$$Y = 132.71 + 9.82K - 1.17K^2$$

where Y and K are grain yield and coded K fertilizer rate, respectively. A maximum yield of 153 bushels per acre was predicted at 164 pound of K per acre.

Table 29 shows the most profitable rates of K for various grain and K prices. These rates are somewhat less than that required for maximum yield. The difference between the most profitable rate and the

Table 29. Potassium (K) rates required for corn to obtain maximum profit at the WIEF site

Corn price - dollars per bu	K_2O - cents per lb		
	4	6	8
$1.50	125	110	91
$2.00	134	116	110
$2.50	139	129	119
$3.00	142	133	125

maximum yield rate narrows as grain prices increase or K fertilizer prices decrease. With corn at 2 dollars per bushel, the most profitable rate declines only 24 pounds if K cost doubles from 4 to 8 cents per pound.

With varying K and corn prices but a constant ratio between the two, the most profitable K rate remains constant. For example, if the cost of K increased from 4 to 8 cents per pound and the price of corn increased from $1.50 to $3.00, the most profitable rate would remain at 125 pounds of K per acre.

The most profitable K rate will vary from year to year, of course, because of variations in price ratios and the many factors that influence yields. Farmers must consider the cost of fertilizer and other production inputs in terms of expected increase in yields and profits.

SUMMARY

The effect of K fertilization and plant population upon the performance of several corn hybrids was studied at four sites during the 1972, 1973, and 1974 growing seasons. The field experiments were located on Webster silty clay loam, Ida-Monona silt loams, Edina silt loam, and Webster silty clay loam soils in northcentral, western, southern, and central Iowa, respectively. Potassium treatments up to 200 pounds of K per acre were applied to the whole plots and plant population levels up to 40,000 plants per acre were used as subplot treatments in a split-plot design for each experiment. The K fertilizer and plant population treatments were applied at the same rates each year to the same plots. A multiple-ear hybrid was used as the test crop in 1972 and 1973 and a single-ear hybrid was used in 1974. Prior to each fertilization, soil samples were taken from the 0 to 6 inch layer of each plot and the nutrient status of the soil was determined by measurement of available P, exchangeable K, and soil pH. Grain yields, percent lodging, stalk quality characteristics, and chemical analysis of leaf samples collected at silking time were used as the main criteria for evaluation of treatment effects.

Each site-year of data was analyzed individually. Analysis of variance, multiple regression, and correlation were used to determine overall treatment effects.

Plant population influenced yields, percentage of barren and multiple-eared plants, lodging, stalk quality characteristics, and corn leaf analyses.

The plant population required for maximum yield varied with year and site. In general, the intermediate populations of 20,000 or 30,000 plants per acre were most effective. The multiple-eared tendency of the prolific hybrids was strong at the lower populations but became nil at the higher populations.

Despite the increased ear set, top yields were not obtained at the lowest populations of 8-, to 10,000 plants per acre, indicating that the hybrids could not totally compensate for reducing the stand to these levels. Hybrid selection was restricted due to the limited availability of seed in quantities required for these studies. As a result, the performance of the prolific hybrids may not have been representative of some of the better genetic material being developed at the present time.

The percentage of barren plants increased significantly as plant population increased. The number of barren plants of the prolific type at the highest plant population was relatively small compared to single-ear hybrids. This suggests that an advantage of the multiple-eared hybrids is their resistance to barrenness at higher stand levels.

Plant lodging increased with increasing plant populations, as was expected. The percentage of lodged plants at harvest time varied widely with site and season, ranging from 2 to 70% at the highest stand.

At the AF site in 1974 plant population significantly affected internode diameter, pith condition, and breaking strength of the second internode of stalk. There was a decrease in stalk diameter, increase in dead parenchyma tissue in the pith, decrease in breaking strength, and an increase in stalk lodging as plant density increased.

Quantities of individual ions in corn leaf samples tended to vary with plant population treatments. Leaf K, Ca, N, and P decreased while Mg increased with increasing plant population, probably due to the increased competition of individual plants for nutrient supplies. Leaf Mg increased with increasing population and seemed to be more strongly influenced by the level of K and Ca in the plant.

Potassium fertilization influenced yields, lodging, and corn leaf analyses. Yield responses varied considerably among sites and years but were generally proportional to the level of exchangeable K in the soil.

Maximum corn yield responses to K fertilization were in the 12 and 15-bushel range at the CWEF, AF, and WIEF site, all of which tested low in K. On the very low testing SIEF site, response reached approximately 30 bushels. Responses were generally largest at the plant populations supporting the higher yields. In all cases, decreasing returns at higher rates of K application were observed. The wide spread between the two K rates used at three sites made it difficult to determine the rates required for the maximum yield. The 50 pound per acre rate was intended to be on the steep part of the response curve while the 200 pound rate was beyond recommended rates.

Potassium fertilizer treatments significantly affected barrenness at the SIEF site in 1972 and the AF site in 1973. As K fertilizer rates increased, barrenness was reduced from 20.8% to 6.2% and from 34.9% to 19.1% for the SIEF and AF sites, respectively.

The lodging problem associated with higher populations was reduced significantly by K fertilization. At the highest plant population lodging averaged 32, 25, 17, and 15% for the 0, 50, 100, and 200 pound per acre K rates, respectively. Potassium rates in excess of those required to produce maximum yield seemed to have little additional effect on lodging.

Leaf K increased but Ca, Mg, N, and P decreased with increasing rates of K fertilization. Added K decreased the sum of the cations in the leaf and increased the K to (Ca + Mg) ratio. As these shifts occurred, yields were increased.

From these data it appears that corn yield responses to K fertilization can be fairly well predicted from the level of exchangeable K in the soil regardless of the soil type involved. On soils testing medium or less, profitable yield increases can be expected from added K fertilizer.

Potassium fertilization can also be expected to reduce plant lodging due to the poor stalk quality often associated with heavy N fertilization, high plant populations, and other intensive management practices. This improvement in stalk quality can be expected to occur largely in the range of yield responsiveness to K.

Additional work is needed to identify the chemical and physiological mechanisms responsible for the influence of K on plant quality.

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APPENDIX

Table 30. Corn yields per plot for the respective K and plant population treatments at individual sites in each year

K rate lb/A	Population 1000 plants/A	Bu/A at 15.5% moisture Block 1	2	3	4	5	6
		CWEF, 1972					
0	10	107.9	95.0	92.9	102.4	98.9	93.1
	20	132.2	123.0	119.5	127.5	120.1	116.4
	30	124.7	129.9	123.0	114.5	117.2	120.7
	40	114.6	116.2	116.5	124.7	115.2	123.4
50	10	102.0	108.2	102.4	103.0	99.8	102.7
	20	124.7	130.0	133.6	127.7	121.0	135.7
	30	132.4	136.3	129.0	121.2	127.2	122.8
	40	122.9	118.8	123.1	120.5	119.3	115.5
200	10	115.7	116.8	113.2	117.2	107.1	103.8
	20	142.8	136.8	132.9	139.2	129.8	124.5
	30	143.8	130.6	133.5	144.3	132.9	132.5
	40	149.5	132.4	129.7	119.7	128.0	125.2
		WIEF, 1972					
0	8	103.8	94.1	96.1	104.1	93.2	92.2
	16	139.3	135.2	117.7	136.0	118.9	139.7
	24	151.5	154.8	110.8	157.5	154.7	146.7
	32	151.0	140.8	140.5	151.4	136.9	137.1
50	8	103.0	93.6	101.9	107.0	100.5	105.7
	16	152.7	142.6	145.3	135.1	144.1	145.6
	24	151.6	153.9	151.1	135.9	150.8	170.9
	32	157.3	143.5	137.5	148.9	155.9	144.7
200	8	107.9	109.8	102.9	101.0	95.8	101.9
	16	138.4	151.6	139.7	138.1	135.9	144.7
	24	154.4	161.3	162.4	142.5	172.6	157.0
	32	156.5	155.2	162.1	159.6	157.4	164.8
		SIEF, 1972					
0	10	96.7	86.0	103.8	109.2	101.0	117.7
	20	128.0	133.4	101.6	124.0	141.2	107.3
	30	144.3	168.8	142.2	139.1	130.5	104.4
	40	123.0	128.7	141.2	132.8	145.0	131.6

Table 30. (Continued)

K rate lb/A	Population 1000 plants/A	Bu/A at 15.5% moisture Block 1	2	3	4	5	6
50	10	82.0	129.2	112.2	121.3	104.3	98.3
	20	147.2	136.5	138.6	142.0	148.0	155.5
	30	161.9	146.7	163.8	164.8	160.8	158.0
	40	153.7	149.6	157.3	156.8	148.9	130.0
200	10	108.7	129.0	109.5	106.0	114.3	113.6
	20	152.4	155.7	157.7	155.7	157.2	163.9
	30	164.1	168.1	155.5	161.9	189.5	164.2
	40	159.5	151.9	157.3	149.2	133.6	164.9
		CWEF, 1973					
0	10	109.3	98.9	103.5	102.8	92.3	102.3
	20	151.5	142.5	129.0	136.5	144.3	131.3
	30	151.1	130.3	126.2	126.7	131.4	125.0
	40	112.2	88.5	124.5	147.8	115.9	122.4
50	10	104.0	112.1	109.9	102.4	113.6	105.3
	20	129.3	137.9	127.4	125.3	124.3	155.0
	30	141.9	128.3	138.7	138.3	124.8	133.4
	40	110.9	120.1	131.9	131.7	125.2	117.3
200	10	117.2	107.7	99.5	104.7	104.2	108.0
	20	144.6	122.1	115.8	137.1	139.5	130.9
	30	168.5	149.9	145.9	151.8	134.7	138.1
	40	135.4	119.9	128.3	114.5	136.5	144.2
		WIEF, 1973					
0	8	100.4	106.6	101.1	105.6	98.1	102.7
	16	128.9	131.3	124.3	144.8	118.4	135.3
	24	130.1	153.1	120.8	126.2	148.7	124.4
	32	123.9	140.1	131.7	140.6	110.9	125.8
50	8	111.6	106.7	117.0	108.9	103.0	103.3
	16	141.7	135.8	127.3	120.4	126.8	133.1
	24	143.3	139.6	133.5	137.4	135.0	132.0
	32	152.4	135.4	134.8	131.2	137.1	133.3

Table 30. (Continued)

K rate lb/A	Population 1000 plants/A	Bu/A at 15.5% moisture Block 1	2	3	4	5	6
200	8	102.7	108.1	106.6	119.4	102.1	112.5
	16	131.0	151.0	141.6	129.7	129.7	128.8
	24	143.1	163.5	152.2	145.5	133.5	142.0
	32	133.2	140.3	145.2	128.3	140.1	129.9
		AF, 1973					
0	10	96.6	96.7	103.1	94.4	87.5	100.8
	20	99.1	121.4	106.4	100.3	122.8	119.6
	30	104.5	117.2	104.0	98.1	93.1	123.6
	40	71.0	85.8	65.6	68.0	88.8	109.2
50	10	99.9	95.3	95.2	95.2	100.1	103.8
	20	134.6	106.0	117.5	126.5	109.8	113.3
	30	108.0	109.9	111.9	115.9	111.4	98.3
	40	87.9	92.3	86.2	104.3	107.7	105.1
100	10	98.6	98.6	105.5	89.8	111.4	92.9
	20	128.2	131.3	122.1	113.7	131.6	136.3
	30	108.6	126.2	116.9	110.0	121.0	125.2
	40	95.8	103.2	101.4	94.6	90.6	114.0
200	10	92.8	88.9	99.7	94.2	98.9	90.6
	20	121.4	115.9	123.8	136.8	128.5	124.6
	30	107.2	113.5	103.6	108.9	115.9	118.5
	40	144.0	81.5	110.0	109.4	121.9	109.2
		CWEF, 1974					
0	10	90.0	84.5	84.9	88.9	81.5	86.2
	20	107.1	86.8	118.5	114.5	97.3	95.7
	30	101.4	110.9	101.7	111.5	94.0	101.8
	40	79.8	91.2	83.6	79.0	88.3	75.2
50	10	96.3	91.2	95.6	91.1	90.4	91.4
	20	110.5	118.3	111.9	115.6	111.8	108.2
	30	118.4	116.2	130.5	116.9	94.1	120.2
	40	71.5	103.5	82.2	92.0	98.0	84.8

Table 30. (Continued)

K rate lb/A	Population 1000 plants/A	Bu/A at 15.5% moisture					
		Block					
		1	2	3	4	5	6
200	10	93.3	95.9	115.2	96.3	93.5	90.7
	20	119.8	115.4	120.2	123.0	115.4	116.1
	30	118.0	86.4	110.0	97.4	119.8	112.9
	40	101.1	93.3	101.1	110.5	96.5	76.9
		WIEF, 1974					
0	8	91.3	91.2	78.2	86.6	83.4	95.0
	16	91.1	95.5	80.5	105.2	81.1	91.7
	24	20.4	77.2	41.4	89.6	68.3	90.6
	32	22.1	17.6	43.4	62.4	31.6	69.1
50	8	86.5	81.2	97.5	78.0	80.6	91.4
	16	86.1	98.4	85.7	77.7	50.1	103.6
	24	58.9	46.1	67.0	48.4	48.8	72.3
	32	36.1	35.1	28.6	50.6	33.0	56.2
200	8	90.2	90.7	92.3	98.0	90.5	85.9
	16	68.5	116.9	94.9	103.6	112.3	78.9
	24	53.1	54.1	94.3	87.2	46.6	75.7
	32	10.2	42.7	42.7	56.8	40.8	37.3
		AF, 1974					
0	10	98.3	108.0	93.0	103.3	99.2	106.0
	20	135.1	142.7	134.0	137.0	135.9	145.0
	30	145.1	129.2	151.0	147.4	144.4	142.8
	40	142.1	119.8	130.9	137.4	105.4	113.7
50	10	98.3	98.7	95.6	98.3	101.8	102.2
	20	105.7	132.7	140.9	141.3	137.4	135.3
	30	104.6	158.6	153.9	150.5	132.3	145.5
	40	105.5	132.2	161.9	129.2	133.4	142.4
100	10	103.5	97.4	98.5	94.3	109.0	106.8
	20	121.5	130.3	157.4	146.5	141.9	145.7
	30	126.4	154.5	151.4	157.2	137.5	147.2
	40	129.2	155.3	158.6	159.5	131.1	146.3

Table 30. (Continued)

K rate lb/A	Population 1000 plants/A	Bu/A at 15.5% moisture Block 1	2	3	4	5	6
200	10	96.1	101.3	95.8	111.7	102.5	104.0
	20	148.2	139.2	145.7	163.0	138.4	150.1
	30	147.0	155.1	160.0	162.4	149.6	143.7
	40	143.0	157.3	159.0	147.1	126.8	149.2